CHAPTER VIII.

THE GEOLOGY OF MOWER COUNTY.

BY N. H. WINCHELL.

Situation and area. This county, which borders on the state of Iowa, opposite Mitchell county, is bounded west by Freeborn county, and north by Dodge and Olmsted counties, and has an area of 711.18 square miles, or 455,155.75 acres. Of this area 1,352.65 acres are water, and 453,803.10 are land. It is represented by plate 12.

SURFACE FEATURES.

Natural drainage. The western line of towns is crossed in a due southerly direction by Cedar river. From the west this stream receives Woodbury, Orchard and Turtle creeks. Its eastern tributaries are Roberts, Dobbin's, Rose, and Otter creeks. Thus the whole western half of the county is drained into the Mississippi through Iowa. The southeastern portion is also drained toward the south through the sources of the Little Cedar, the Wapsipinicon and the Upper Iowa rivers. The northwestern portion of the county is drained by the headwaters of the Root river toward the north and east. This river flows eastward through Fillmore and Houston counties into the Mississippi near La Crescent. The divide between streams running north and those running south crosses Mower county from S. E. to N. W., nearly through the center, and includes some of the highest land in that portion of the state. The highest point in the county, on the Southern Minnesota R. R., is at Dexter station, in sec. 13, town **103** N., range **16** W., 786 feet above the Mississippi at La Crosse, or 1,412 feet above tide water.

These streams are all small, and some of them become nearly dry during the summer. Some of them furnish water-power at a number of

places. This has been improved on the Upper Iowa at Le Roy, and on the Cedar at Ramsey, Austin and at several places below Austin, in the construction of flouring mills.

Water-power and water-power mills in Mower county.

At Lansing on the Cedar is the *Lansing mill*, owned by Alderson and company; head ten feet; thirty horse-power; one "American turbine" wheel of forty-two inches; five sets of rollers (Noyes); capacity, seventy-five barrels per day.

At Ramsey is Matthew Gregson's mill, which has a head of water of nine feet; one forty-two-inch Leffel wheel, with twenty-five horse-power; one other wheel for machinery, giving thirty horse-power; three run of stone; capacity fifty barrels.

At Austin is *Warner's mill* (now owned by C. Alderson), situated on Dobbin's creek, with sixteen feet head; two Huston wheels (17 and 15 inches); fifteen horse-power, more or less, for each wheel; one pair of millstones; five sets of rollers, of Cosgrove's patent; capacity forty barrels. The full capacity of this stream is about twenty-five horse-power.

At Austin on the Cedar is the *Engle roller mill*, owned by Job Engle; has eleven feet head; two Huston wheels (45-inch and 27-inch), giving respectively forty and fourteen horse-power; eleven sets of single (Noyes) rollers; capacity 125 barrels.

Two miles below Austin on the Cedar is Jonathan Gregson's mill, with thirteen feet head; it has one Leffel wheel of forty-two inches, and one "American turbine" of forty-two inches, making together 100 horse power; eight sets of rollers (Case's patent); two buhrs; capacity 125 barrels. This power is not all employed.

Five miles below Austin is W. H. Officer's mill; this has eight feet head, one "American turbine" and one Leffel wheel, each being forty-eight inches in diameter; sixty horse-power; two sets of rollers (Noyes), and three run of stone.

At seven miles below Austin on the Cedar is the old site known as *Tiff's mill*, now owned by Alderson and company. This has not been employed for twenty years, and a part of the dam is gone; but there is here available over 100 horse-power.

There is another available privilege near the mouth of Rose creek, amounting to ten horse-power, not now used.

At Le Roy, on the Upper Iowa river, is Isaac H. Thompson's mill; this has ten and a half feet head; one forty-eight inch Leffel wheel; three run of stone (one for feed); capacity twenty-four barrels.

Topography. This county is one of high prairie. Its surface is smooth, and gently undulating. The broad valleys of the small streams that appear in the eastern and western portions are basin-shaped in cross-section, though they sink, in the towns of Frankford and Racine, from fifty to seventy-five feet below the general level. The summit of the principal N. W. and S. E. watershed is formed by the Lower Devonian strata. Toward the east from this summit, particularly toward the northeast, the view over the valleys of Deer and Bear creeks, introduces a decided change in the landscape as it first appears before the traveler. The expanse is broad, low, and wooded more or less. A similar change is introduced in the southeast, where the Upper Iowa river passes through the township of Le Roy. The western

Elevation.]

portion of the county is considerably lower than the central and eastern. This is owing to the valley of the Cedar, the effect of which is felt over a wide belt, in depressing the general level. The southern townships of Lyle, Nevada and Adams may be characterized as flat. The same is true of much of Marshall, Windom and Austin. There are extensive tracts of prairie in the central and eastern townships that are still in their pristine condition.

Elevations. The following points of elevation above the ocean will give the average altitude along the railroad lines, and this can not vary much from the actual average for the county, since the roads easily follow the undulations of the prairies with very little of either cutting or filling.

Elevations on the Southern Minnesota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from La Crosse.	Feet above the sea.
Spring Valley (Fillmore county),	73.6	1266
Summit (grade),	80.1	1358
Grand Meadow,	83.0	1338
Depression (grade),	85.2	1317
Dexter,	89.8	1412
Brownsdale,	98.0	1271
Cedar river (water),	102.9	1192
Ramsey (crossing of the Chicago, Milwaukee and St. Paul railway),	103.1	1214
Depression (grade on bridge at Turtle creek),	107.7	1197
Oakland (Freeborn county)	109.9	1265

Elevations on the Iowa and Minnesota division of the Chicago, Milwaukee and St. Paul railway.

	Miles from St. Paul.	Feet above the sea.
Madison,	90.2	1250
Lansing,	93.8	1224
Ramsey (crossing of the Southern Minnesota railway),	96.3	1215
Cedar river (water),	96.7	1185
Cedar river (grade),	96.7	1200
Wolf creek (bridge),	97.7	1203
Austin,	99.3	1197
Dobbin's creek (water),	99.6	1175
Dobbin's creek (grade),	99.6	1194
Austin Junction,	99.8	1194
Rose creek (bottom),	107.3	1222
Rose creek (grade),	107.3	1236
Rose Creek station,	107.7	1245
Summit (grade, cutting 7 feet),	111.1	1301
Little Cedar river (water),	111.9	1252
Little Cedar river (grade),	111.9	1272
Creek bottom,	113.8	1259
Creek crossing (grade),	113.8	1274
Adams,	114.1	1276
Summit (grade, cutting 2 feet),	117.0	1343
Taopi,	117.9	1336
Creek bottom,	122.7	1270
Crossing of creek (grade),	122.7	1285
Creek bottom,	123.2	1268

	Miles from St. Paul.	Feet above the sea.
Crossing of creek (grade)	123.2	1285
Summit (grade, cutting 5 feet),	124.0	1300
Le Roy,	125.4	1280
State line (natural surface and grade),	126.0	1263
Elevations on the Austin and Mason City branch of the Chicago, Milwaukee and St. Paul railway.		
Austin Junction,	99.8	1194
Rose creek (water),	103.1	1165
Rose creek (grade),	103.1	1185
Summit (grade),	104.6	1212
Depression (grade)	109.3	1185
Lyle,	110.5	1199
At state line (grade),	110.9	1186

Mean elevation of the county. Estimates of the average hight of the townships of this county are as follows: Racine, 1,300 feet above the sea; Franklin, 1,320; Bennington, 1,325; Le Roy, 1,300; Pleasant Valley, 1,350; Grand Meadow, 1,360; Clayton, 1,360; Lodi, 1,325; Sargent, 1,360; Dexter, 1,360; Marshall, 1,330; Adams, 1,275; Waltham, 1,340; Red Rock, 1,270; Windom, 1,240; Nevada, 1,230; Udolpho, 1,260; Lansing, 1,225; Austin, 1,200; Lyle, 1,190. The mean elevation of Mower county is approximately 1,300 feet above the sea.

Soil and timber. The county is distinctively one of prairie, yet it has considerable timber along the streams. This is particularly the case along the Upper Iowa river in the southeastern part of the county along the eastern tributaries of the Root in Frankford, and along the Cedar crossing the whole width of the county. There is also an important tract of timber in Nevada township.

The soil of Mower county is everywhere dependent on the nature of the drift. The underlying rock has affected it only so far as it may have mingled with the general mass. It is hence primarily a gravelly clay, that being the character of the subsoil throughout the county. This gravelly clay, however, is not now prominently displayed as the immediate soil of the surface. Indeed, the farmer in plowing rarely penetrates to it. It lies below a rich loam usually at depths varying from zero to two or three feet, or even more. The surface soil itself, which has resulted from it through the agency of theforces of the atmosphere and of vegetation, is of a dark color, and in general may be designated a clayey loam, or a sandy loam, depending on the nature and completeness of the local drainage. In low grounds this loam is thick and of a dark color. It is also apt to be more clayey in low ground

than it is on the hillsides or slopes adjoining, and on high hills or steep slopes it is thin or wanting, the wash of the surface having carried it into the valleys. Along streams it often consists of an arenaceous loam variously mingled with the detritus of the flood-plain.

The soil of the county is everywhere characterized by the strength and fertility that the drift soils of the Northwest are noted for. They are the most reliable soils, for all the purposes of the farmer, that are known. The states that are regularly and deeply buried in drift deposits are known as the best farming states of the union. Certain rock soils, endowed with unusual special qualities, may excel in the production of certain crops, especially in favorable seasons, but for general tillage they cannot compete with the homogeneous drift soils, through which are disseminated the good qualities of the various rocks concerned in their production, in the proportions that make stability and diversity equally certain.

In the examination of the county the native varieties of trees and shrubs were noted, and the following list comprises the species that were seen. In respect to the trees it is probably nearly complete for the county, but there are doubtless other species of shrubs.

Trees and shrubs of Mower county.

Quercus macrocarpa, *Michx.* Bur oak.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Populus tremuloides, *Michx.* Aspen.
Ulmus Americana, *L.* (*pl. Clayt.*), *Willd.* American elm.
Salix——? Different species.
Corylus Americana, *Walt.* Hazelnut.
Rhus glabra, *L.* Sumac.
Ostrya Virginica, *Willd.* Ironwood.
Tilia Americana, *L.* Bass.
Sambucus Canadensis, *L.* Elder.
Symphoricarpus occidentalis, *R. Br.* Wolf berry.
Ribes Cynosbati, *L.* Prickly gooseberry.
Cornus (sp. ?) Cornel.
Pirus coronaria, *L.* American crab-apple.
Cornus stolonifera, *Michx.* Red-osier dogwood.
Alnus incana, *Willd.* Alder.
Populus monilifera, *Ait.* Cottonwood.
Cratægus coccinea, *L.* Thorn.
Prunus Americana, *Marshall.* Wild plum.
Prunus serotina, *Ehr.* Black cherry.
Vitis cordifolia, *Michx.* Frost grape.
Celastrus scandens, *L.* Climbing bitter-sweet.
Ribes floridum, *L,* Black currant.
Rosa blanda, *Ait.* Wild rose.
Cratægus Crus-galli, *L.* Cockspur thorn.

Fraxinus Americana, *L.* White ash.

Carya alba, *Nutt.* Shag-bark hickory. At Lansing, and in the valley of the Cedar, one foot in diameter.

Acer saccharinum, *Wang.* Sugar maple.

Carya amara, *Nutt.* Bitternut.

Pinus strobus, *L.* White pine. Along the rocky banks of the streams in the eastern part of the county.

Ulmus fulva, *Mich.* Slippery elm.

Fraxinus sambucifolia, *Lam.* Black ash.

Viburnum Opulus, *L.* High-bush cranberry.

Rubus villosus, *Ait.* High blackberry.

Juniperus Virginiana, *L.* Red cedar.

THE GEOLOGICAL STRUCTURE.

Of the older rocks the lower portion of the Devonian and the upper portion of the Lower Silurian are found within the county, dipping toward the southwest. The western portion of the county is known to be immediately underlain by the Lower Cretaceous, without ascertainable eastern limits. The underlying rock is nearly everywhere hid by the drift, and for that reason the actual position of the boundaries of the formations is unknown. It is possible, indeed probable, that the Cretaceous area extends farther east through the northern part of the county, since traces of it are found in the northern part of Fillmore county. The central and northwestern parts of the county are underlain by the argillaceous sandstone, and associated shales, which are seen at Austin. In Pleasant Valley and Racine townships a limestone which is the extension of the Galena and Upper Trenton is found. This lies below the Austin rock. The Devonian limestones, which overlie the Austin rock, occupy the southern and southeastern townships, and the western portions of Lyle and Austin, on the west side of the Cedar river. The stratigraphy of the formations is as follows, in descending order. Nothing is known of their thickness, except what can be learned from a study of their outcrops in other counties. There is no reason to suppose they vary much in that respect from the descriptions that have been given already of them in Fillmore and Olmsted counties.

Cretaceous.	1. Blue clay. 2. White sandstone. 3. Pebbly conglomerate.
Devonian.	4. Limestone, fine grained, dolomitic. 5. Limestone, coarse grained, dolomitic. 6. Argillaceous sandstone.
Silurian.	7. Calcareous shale. 8. Limestone, dolomitic, with shale beds.

The Cretaceous. The principal exposures of the Cretaceous are found in the valley of the Cedar river, and in the vicinity of Austin. These less indurated strata overlie unconformably, with an immense lapse of intervening time not here represented by any rocks, the older rocks of the Silurian. They have been broken up by the glacial forces, and their materials have been forced into the pre-existing cavities and channels of the older strata. They also lie undisturbed in some of these old cavities. Similar apppearances have been noted in Iowa by Profs. Hall and Whitney and by W. H. Barris,* but in that state they seem not to have been referred to the agency of the Cretaceous ocean.

With respect to the *clay*, which is probably the uppermost of the Cretaceous deposits in the county, it is frequently seen at Austin, and at points below Austin, in the quarries that are opened in the Silurian rocks. A quarry in the left bank of Dobbin's creek, just below the mill of Mr. C. Alderson, opened in the Austin rock, shows the beds everywhere greatly broken. Throughout, the partings and all the interstices are closely filled with this greenish clay. The clay here very rarely has any distinct bedding. It varies from green to reddish, or buff, and is accompanied also with considerable clean white sand. These are both lodged in the cavities of the rock in such a manner that they seem to have been jammed into them. They pertain to no particular horizon, and show no definite arrangement. They are disposed everywhere, from the top to the bottom of the bluff, though the sand seems to be more abundant near the bottom.

At a quarry of Mr. Alderson's, near Austin, the rock was overlain by the following

Cretaceous clays.

1.	Black sandy loam and soil,	2 to 4 feet.
2.	Band of red and variegated compact clay,	6 in. to 4 feet.
3.	Yellow ocherous band of clay	6 in. to 4 feet.

The superposition of these bands of clay is not so regular as indicated by the foregoing section. Occasionally number 3 is broken through, or is wanting, and number 2 lies on the rock, or passes down into its crevices; yet number 3 is generally the first over the rock. They vary in thickness and swell out in shapeless masses, and become very hard when dry. Such hard masses are seen sometimes to embrace bits of angular earthy rock,

*See the second annual report, and the report on Blue Earth county; also, *Geology of Iowa*, Vol. I., pp. 84 and 130: also, *Proceedings of the Davenport Academy of Natural Sciences*, Vol. II., p. 264.

much like ocher, varying in color, from a dark burnt-umber color to a lighter shade, even to buff, and appearing when of a light color much like the mass of number 3. They can be scratched easily with a knife, and however black they may be, they give a red hæmatitic streak. When they are faded the streak also fades into a brown or yellowish-brown like limonite. Intermingled very irregularly with number 2, and sometimes also with number 3, are masses of greenish clay which has in every other respect the same outward characters as number 2. There are here also large, crystalline, detached masses of apparently a siliceous limestone which is very hard and close-grained. In some cases, however, this varies to a porous and nearly white limestone that appears to be very pure.*

In the digging of Mr. L. G. Basford's well, at Austin, the rock quarried at Austin was struck at twenty-four feet and was penetrated eight feet. Overlying this was a deposit of blue clay. This deposit was also found in the crevices of the rock. The clay contained angiospermous leaves. Two distinct varieties of leaf were discovered, one resembling *Diospyros primæva*, Hr., and the other a species of *Sequoia*. The specimen of the latter consists of a branch, apparently of a small herb. It shows an inch and three-fourths of the main stalk. In that distance it gives off four branches, each of which seems to be as large as the main stalk, three on the left and one on the right. The whole specimen is thickly furnished with decurrent, parallel-veined leaves, which have a distinct midrib. The leaves are simple, entire, oblanceolate-linear, and taper-pointed at their junction with the stalk. Their length is a quarter of an inch, varying a little above and below that size, and their width is one-twentieth of an inch. The diameter of the stalk, and that of the branches, is about one-half the width of the leaves. The latter diverge from the branches at an angle of 40° to 45°. A photographic copy of this fossil was submitted in 1874 to Dr. J. S. Newberry, who pronounced it probably a species of *Sequoia;* and Dr. Leo Lesquereux, on examination of the original specimen, regards it as a new species.†

Near the mill of Jonathan Gregson, about two miles below Austin, the palæozoic rock is cut by old channels and other cavities, and these are filled with blue clay of the same character as that containing the angiospermous leaves at Austin. It shows here no fossils nor shells of any kind. It is exceedingly fine and plastic. It is said to run down at least thirty feet, where the stone itself would naturally lie if the strata were continuous. It seems to occupy a trough-like excavation in the rock about a rod wide running east and west, and has been traced by means of an iron rod several yards back from the river bank. This clay below twenty feet is said to become white.

Besides this clay there is a *white sand*, supposed to underlie the clay,

*In connection with this description of limestone masses, it is interesting to note the occurrence at St. Charles, in Winona county, of hard siliceous limestone masses on the surface of the ground, appearing very much like those embraced in this clay, and also in Fillmore county southeast of Spring Valley.

†In the first and third annual reports these fossil leaves were wrongly referred to the Austin rock, and on the strength of that information the Austin rock was regarded Cretaceous. A late re-examination of the locality, and an interview with Mr. Charles Bromwick, have established the fact that they are only found in the clay deposit overlying the rock.

also belonging to the Cretaceous. This has already been mentioned at Alderson's mill on Dobbin's creek, but its most interesting appearance is at Sargent's spring, S. W. ¼ sec. 31, Red Rock. It is below the level of the water of a little pool. Pure, soft (?) water boils up over the area of about a square rod, and sometimes over double that area, and can be seen issuing from the ground, bringing with it clean white sand. The bottom of the pool presents a beautiful appearance. The water is as clear as crystal, and the boiling points which appear by reason of the rising white sand, in the midst of the darker sediment, can be minutely inspected at a depth of five or six feet. Running a stick into the agitated sand, it soon strikes a sandrock which is doubtless the source of the boiling sand, and the same bed that furnished that at the quarry in Dobbin's creek.

There is also a *white pebbly conglomerate*, which passes into a ferruginous grit, found in the eastern part of the county, that is referred, with some doubt, to the Cretaceous age. This has been mentioned in the report on Fillmore county.* It is seen in the north half of section 13, Frankford, in the north-and-south road. It is here a ferruginous, pebbly conglomerate, presenting a small surface outcrop, overlain by loam. It produces a sandy road, and sandy soils in the adjoining fields for a quarter of a mile next north. Again, at the middle of section 12, in the same township, is an exposure of the same in the road. A perpendicular thickness of about ten feet of bedding seems to be here involved, in a weathered down and half-covered outcrop. This is the highest land between the two creeks. The same rock appears again on the N. E. ¼ sec. 11, overlying a disintegrating shaly and limy rock like that under the Devonian limestones in Fillmore county, and the same as that seen in the road about a mile and a half north of Grand Meadow. At this place, however, the heavy magnesian beds are not in outcrop. At the S. E. ¼ sec. 3, in the road running east and west this rusty conglomerate is conspicuous. It is disintegrated so as to make a gravel, as in Fillmore county.

As already intimated, the age of this conglomerate is not established beyond doubt. The appearances will justify its reference to the Cretaceous, and the occurrence of similar rock in other counties where it is impossible to refer it to the age to which it may belong in Mower and Fillmore coun-

*See also the reports on Nicollet, Hennepin and Wright counties. Similar conglomerates appear in the Lower Cretaceous in Guthrie county, Iowa. See *Geology of Iowa*, 1870, Vol. II., p. 100.

ties, confirms that reference. Still, as the gritty conglomerates seen in other counties may not be the same as this, it is necessary to mention another possible explanation of this conglomerate. It may be a representative of the *Oriskany sandstone.* This sandstone lies at the base of the Devonian limestones in New York. It is well known in Ohio where it is sometimes quite coarse-grained, and involves pebbles of the Waterlime* which underlies it. In Illinois it is recognized by the fossils it contains, and has the local designation *Clear Creek limestone*, although its beds are cherty and siliceous. It has not been identified either in Iowa or Wisconsin. As the Upper Silurian limestones are wanting in the series of strata in Fillmore county at Spring Valley, there seems to have been some movement in the ocean level which caused the deposition of the Devonian directly upon the Lower Silurian. Such an agitation of the ocean's bed as would produce a conglomerate in Ohio, burying it under a sandstone like the Oriskany, or an arenaceous dolomite like the Lower Corniferous of that state, must have had its accompanying effects in other portions. The gradual disappearance of the Niagara limestone, the only representative of the Upper Silurian in northeastern Iowa, as it approaches Minnesota, and its entire absence at Spring Valley, seems to indicate an encroaching ocean. Such a movement would necessarily have buried its own beach-deposits beneath the sediments of its advancing oceanic waters, and may have produced a conglomerate stratum like that seen in Mower county. If this conglomerate could be found lying below the Devonian limestones, this hyopthesis would be sufficiently established, but unfortunately the drift and loam are so prevalent that the stratigraphic relations of the two have not been made out; at the same time it must be admitted that all the outcrops of the conglomerate that have been seen in Fillmore and Mower counties are so situated with respect to the strike of the limestones as to allow of the infra-position of the conglomerate.

All of these Cretaceous rocks, whether clay, sand or conglomerate, are comparable with similar rocks seen in the Minnesota valley and its tributaries, situated from seventy-five to one hundred miles west-northwest from Austin.†

*Report of the Geological Survey of Ohio. Part I. Geology, Vol. II., p. 301. Geological Survey of Illinois, Vol. III., pp. 24, 37, and 62.

†See further respecting possible Cretaceous outcrops, under *Hudson River rocks.*

The Devonian limestones. Beginning with the uppermost of the Devonian strata, we find a *fine-grained dolomitic limestone*, quarried at Le Roy, in the southeastern corner of the county. It is exactly like that seen near Northwood, Worth county, Iowa,* a few miles south of the Minnesota state line. The full thickness of these strata cannot be stated, but about fifteen feet can be assumed for their maximum thickness at Le Roy. They contain stromatoporoid corals, and but very few other fossils. In some quarries a few beds of shale three or four inches thick can be seen between the limestone beds.

Thomas Kough's quarry is three-quarters of a mile east of the village, and exposes six feet of fine-grained beds that have a perceptible dip toward the northeast. The quarries of Joseph Brevier, of which two are opened, are in the left bank of the Upper Iowa river. The rock here is fine-grained, and in beds from three to six inches thick. On the land of F. Brevier, where the highway crosses the river on sec. 27, can be seen the underlying beds that differ much from the stone quarried at Le Roy. They appear at the spring just below the bridge, and exhibit about two feet of strata. They are granular, vesicular, and when wet rather soft; the upper part being confused and indefinite in stratification, in transition from the overlying compact beds and the magnesian rock seen on Beaver creek in Fillmore county and at Chester, Iowa. They show a slight dip to the south. The quarry of Widow Cady Palmer is at the road-crossing of the north fork of the Upper Iowa river on sec. 21, Le Roy. Levi Alsdorf's quarry, S. E. ¼ sec. 21, Le Roy, shows about ten feet of beds, parted by layers of one to three inches of shale, with a slight dip to the southeast. The quarry owned by the heirs of L. Johnson is about forty rods from the state line, in sec. 35, Le Roy. It is in a lightly timbered tract of country, accompanying the Upper Iowa river, and about ten rods south of the river. The beds rise to within a foot or two of the surface, on the the angle of the river bluff, though the bluffs of the river are not conspicuous, the depth of the valley being only about ten or fifteen feet below the general level, and broad and basin-like. The foreign drift about is light, but some large boulders are scattered about. This stone is light-colored (nearly white), hard and fine, exactly like the Devonian seen near Northwood in Iowa, though in heavier beds than that. It would make a beautiful white marble. It is uniform in texture, and not in the least porous. With the exception of one or two layers of an inch or two of green clay, the beds are all of this limestone, exposed twelve feet. At Judson A. Palmer's quarry, the rock is overlain by six inches of soil, though a hundred rods from the river. These beds are all badly weathered, so far as opened, and show no important variation from the other quarries; exposed three feet. Mr. Palmer's other quarry is in the river bluff and has furnished stone that has been burned for quicklime. The stone is the same as that already described. Drowne's quarry is also in the bank of the river, but shows only about six feet, though there is every opportunity for opening the beds to a greater depth. There is here a more argillaceous and fissile bed than any in the other quarries. It is about eighteen inches thick. This layer, coming about midway in the quarried beds, facilitates the working of the quarry, but is itself of no value. In the debris thrown out, probably from this layer, a globular mass of *Cœnostroma* was obtained. There is an exposure of the limestone in the valley of the Upper Iowa, near the west line of the S. E. ¼ of N. W. ¼ of sec. 29, Le Roy. There is here a boiling spring, coming out of the rock, in the bed of the creek. The rock is also exposed just over the state line in Iowa, on the Little Cedar, and more particularly at Staceyville, two miles south of the line.

Underlying the above is a *granular, often vesicular, dolomitic limestone.*

*At Northwood are numerous walls and foundations built of stone exactly like that of the numerous boulders that are distributed over Freeborn county and counties further northwest many of which have been burnt for quicklime. The layers are about four inches in thickness, but sometimes are eight inches, very close-grained, and of a light cream-color. Still in the center of the thick beds is a blue spot, indicating the original blue color of the whole. Only a small outcrop of these beds occurs at Northwood but three miles farther south, on the Shell Rock river, these beds appear again and have been opened. They are here horizontal and vary from three to ten inches in thickness. The only visible fossils are badly weathered, and show on the outer surfaces. They are *Favosites, Cœnostroma, Acervularia*, and perhaps one or two other corals. At Beckett's quarry about six feet of very hard, fine-grained beds are visible.

This appears but slightly at Le Roy, but is found along the Upper Iowa at Chester, seven miles below Le Roy, and on Beaver creek in Fillmore county.* It appears also in the northeastern part of the county, and in the southwestern. Its original line of strike probably crossed the county nearly east and west, through the central portion, and it is possible that this rock reaches still as far north as Brownsdale, but it has been driven southward by the erosive action of meteoric forces, particularly by the "drift" forces, and by the action of the Cedar river, so that it now has a flexure toward the south, even to the Iowa state line, along the Cedar valley, and its area in the county is separated into two parts. As near as it is possible to judge from the facts known, the strike of the lower beds of this limestone is shown on the plate of Mower county.

In the southwestern corner of the county, sec. 33, Lyle, are the quarries of Mr. John Beech, one of which is on the south side of Woodbury creek, east of the north and south road, and the other is on the river bank about twenty rods south of the mouth of the creek. Here are seen about eighteen feet of rough magnesian limestone beds, gradually dipping south and entering the river before reaching the state line. They are the cause of the water-power at Otranto, a few miles south, in Iowa, where flouring mills have been erected. These beds are firm, but very rough and cavernous, curly with concretionary structure and with rusty films that penetrate them. The only fossils discovered are the impressions of a coarsely ribbed *Atrypa*, having all the appearances of the so-called *little turtles*, seen in a similar rock at Spring Valley in Fillmore county. Indeed, the whole aspect of the rock is like that of the coarse rock containing those fossils. This rock here overlies the Austin rock, though the actual *overlie* cannot be seen. Its manner of approach to the river, and the topography toward the south and west, taken in connection with its dip and the relation it bears geographically to known outcrops of the Austin rock, are the only evidences. The strike of this limestone from Beech's quarry northward can be followed on the west side of the river by the terrace elevation which they cause, running about a mile west of the river. Where this terrace is crossed by Orchard creek, sec. 29, Austin, lime was burnt some years ago. Toward the north further this terrace recedes from the river, apparently

*See the Fillmore county report, p. 305.

leaving the county on the south side of Turtle creek. On the east side of the Cedar river a similar terrace, or bench of more elevated land, skirts the valley through the township of Lyle, bearing away from the river toward the valley of Rose creek, where the limerock is again exposed slightly on the land of Andrew Robertson, sec. 26, Windom, in a little valley tributary to Rose creek. The same or similar beds are next seen on the S. W. ¼ sec. 20, Frankford, where Mr. Aaron Bush quarries them in the valley of Deer creek. Here the rock is parted into blocks that are quarried out without blasting or breaking. They are much faded and rotted *in situ*, having over them only a thickness of about four feet of loam. The beds are from six inches to two feet thick, and amount to about ten feet altogether. The stone is very good for all masonry. It is easily dressed and has a yellowish buff color. On the S. E. ¼ sec. 30, Frankford, the same rock was struck in the well of G. C. Easton, and was drilled into sixty or seventy feet. The abutments of the iron bridge (over the pond) on sec. 20, are from Bush's quarry. The stone is firm and quarried in blocks three feet long and about twenty inches thick. There is another quarry not much worked a short distance below this bridge, in the banks of the creek. The rock quarried at Bush's appears in the south bank of Deer creek, at Frankford, nearly on the county line, overhanging and perpendicular, in heavy beds from two and a half to four feet in thickness. It is vesicular, as there, and porous, and even cavernous, rough exteriorly, and presents the aspects of the coarse, magnesian beds of the lower Devonian limestones as seen at Spring Valley, containing also the peculiar atrypoid casts known as *little turtles*. This is on the land of John Hawkins. Again, on the S. W. ¼ sec. 2, west of both crossings of Bear creek, similar heavy beds of magnesian limestone are seen, but nothing can be affirmed of their equivalency with those at Frankford. These appear to be overlain by the rusty conglomerate supposed to belong to the Cretaceous.

The so-called *Austin rock* underlies the foregoing coarse magnesian strata. This stone, as it appears at Austin, is a fine-grained sandrock, or shaly sandrock, that cracks like some shales after exposure to the weather. In some places, further down the river, it is a fine, calcareous sandrock. The texture of the stone itself is close and the grain is homogeneous. Some slabs have been sawn for bases to tombstones. It is more safely sawn to

any desired dimension than cut or broken, since it fractures treacherously; yet it is not in the least crystalline. Although a sandstone it contains no apparent grit, and is useful for fine whetstones, or for hone-stones. As seen about the city it is very generally of a dirty buff color to the depth of half an inch or even three inches, depending on the amount of weathering or oxidation. The thinner beds are altogether changed to that color. In the center of the beds, however, in the deeper parts of the quarry, the stone is blue. The presence of occasional concretionary iron-and-mud balls causes a rusty stain ef a yellow color over the surface of many of the slabs. These concretionary balls fall out, or dissolve out when in the water, and leave cavities that become larger still. Some other cavities that have been protected within the homogeneous rock, on fracturing the rock are seen lined with drusy quartz, and the quartz is sometimes coated with a limonite scale. The rock contains very sparingly a few molluscous fossils. These are generally too much absorbed, or too fragmentary, to admit of specific identification. Among these Prof. H. S. Williams has made the following determinations, which, however, are to be regarded "as nothing more than strongly probable," viz: numerous cavities of *Aulopora*, or some allied form, a small shell like *Atrypa reticularis*, and another like *Atrypa aspera*, H., *Cyrtina*, like *C. Dalmani*, but perhaps *C. Hamiltonensis*, several lenticular-shaped shells which are probably *Nucleospira*, a minute terebratuloid shell of *Rensselaeria* type, trace of a crinoid stem, and a trace of a minute *Orthoceras*. At Gregson's mill he has also identified the following, viz: *Productella truncata*, Hall, a minute lamellibranch like a small *Aviculopecten*, and a minute brachiopod of an oval, smooth surface resembling a dorsal valve of *Ambocœlia* or (?) *Nucleospira*. On the strength of these Prof. Williams is of the opinion that the fauna belongs to an horizon near the base of the Hamilton, either below it or in an equivalent position to the New York Marcellus.

At the mill of J. Gregson, about two miles below Austin, a great deal of stone has formerly been taken out, but now the quarries of that neighborhood are nearly all flooded by water of the dam. The chief quarry was just above the present site of the mill and near the dam, on the left side, though just below the dam the rock shows on both sides and has also been wrought. The following downward section was seen at this point.

Section at Gregson's mill.

No. 1. Black loamy soil..... ..... 7 to 8 feet.
No. 2. Loose fragments of the underlying beds, and clay, mixed..... 3 feet.

Devonian limestones.]

No. 3. Heavy stone like that described at Austin, with clay filling the open planes and joints.....10 to 12 feet.

No. 4. Rusty bituminous films.....½ to 1 inch.

[On the authority of the owners of this quarry, to this section may be added the following:]

No. 5. Limestone, filled with shells, blue, contains flint, makes lime, penetrated.....3 feet.

The bedding of No. 3 is here broken in a manner similar to that of Alderson's quarry at Austin. The corners and angles of the beds are replaced by clay and the color of the stone is changed from blue to buff or drab, to the depth of about two inches.

Some years ago the rock was worked by Dr. Barns, of Austin, about half a mile above Gregson's mill. This quarry is now almost entirely flooded by the dam. The abutments of the upper bridge at Austin came from this quarry, in part. Judge Ormanzo Allen owned a quarry still above Barns that was also considerably flooded by the same means. The quarry most worked was just above the mill, owned by M. J. Woodson. It is now entirely under water. Stone is still taken out, however, all along, both above and below Gregson's. The beds at Gregson's show very nearly the same characters as at Austin. The descent of the stream is over about fourteen feet of rock, the layers of which are sometimes two feet or more in thickness, or massive, much like an indurated shale. In weathering these thick beds are checked by planes running mainly horizontal, instead of perpendicular or diagonal. Although mainly horizontal, these planes are apt to unite after a few feet, splitting up the heaviest beds into wedging, lenticular masses. Some parts are here plainly calcareous, affording traces of fossil remains that have the appearance of brachiopods. These portions are porous as if by the absorption of fossils.

At the mouth of Rose creek about the same thickness of the same kind of stone can be seen in the bed and banks of the creek. A fine exposure is owned by J. D. Woodard in the right bank of Rose creek near the crossing of the road from Austin to Officer's mill, perhaps a mile above its union with the Cedar. It is again seen above Officer's on the land of Col. Lewis, on the east bank.

At W. H. Officer's mill the left bank of the river shows about twenty feet of bedding. This is one mile below Rose creek. South of this mill rock of the same kind is seen at a number of places before reaching the state line. At two miles below Officer's it is quarried on R. B. Foster's land, and on Mrs. John Niles's, sec. 4, Lyle. At the last place it verges more toward a sandstone. It has been put into the foundation of a proposed mill by Alderson and company.

Two miles east of Officer's mill a farmer struck the same rock in two separate wells on his farm, in one at the depth of three feet and in the other at eleven.

Dobbin's creek, which joins the Cedar at Austin from the northeast, furnishes a water-power of fourteen feet by dam, where a mill is erected. A quarry in the left bank of this creek shows the same rock. The bluffs of the creek just below the mill rise about thirty feet, and show about twenty feet of rock. The beds are in every place greatly broken, and in some cases displaced. The rock is parted into blocks of varying size, according to the thickness of the layers, the uppermost being finest. Throughout, the partings and all the interstices are closely filled with Cretaceous clay, making the whole a close and almost impervious mass. It has very much the aspect of the Cretaceous on the Cambrian, as seen at Mankato,* except that the small cracks and openings are here all filled densely with the clay.

On the S. E. ¼ sec. 12, Windom, Mr. Thomas Smith struck the Austin rock in making explorations for coal, at a depth of about 34 feet. In the extreme northwestern corner of Mower county it was struck by a farmer in digging a well. It there has the form of the fine-grained sandstone seen at Austin. The surface features that prevail at that point pass into the northwestern corner of Fillmore county, and cover the most of Sumner township. Southward, at Spring Valley, a similar stone appears in the north side of the creek, where it has been opened for building purposes by Mr. James Wilder and Henry Thayer. This stone is, however, more dolomitic, and contains large *Strophomenæ*, and is thought to be allied to the Lower Silurian, though its palæontology has not been learned yet sufficiently to warrant any positive sentiments concerning its age.

Hudson River rocks? At two points within the county has been seen

*See the second annual report; also the report on Blue Earth county.

a light-colored, crumbling calcareous shale or clay which may belong to the Hudson River epoch. No fossils have been found in it. It has more resemblance, lithologically, to some Cretaceous beds,* but it holds, geographically, the right position to fall within the shale seen at High Forest in Olmsted county. This differs from that, however, in not being so coarse, nor in any degree arenaceous. The points referred to are both in the northeastern corner of the county. Along the road a mile and a half north of Grand Meadow it appears in a weathered and washed sloping exposure, near the crossing of the north fork of Bear creek. No other rock is to be seen in the vicinity, and nothing indicates its stratigraphic relation to other strata except that it occupies a position somewhat more elevated than the rock quarried by Mr. Bush, about a mile east of Grand Meadow. An exposure of similar shale is visible in the N. E. $\frac{1}{4}$ sec. 11, Racine, by the highway, east of the easterly crossing of Bear creek. This outcrop is topographically lower than the Cretaceous conglomerate seen in the immediate vicinity in the highest land.

The Galena and Upper Trenton. This limestone strikes across the northeastern corner of the county, and doubtless there are some exposures of it in the banks of the streams in Pleasant Valley and Racine, but none of them have been seen.

THE DRIFT.

It is only in the eastern portion of the county, and mainly in the northeastern, that there is any noticeable deposit of the loess loam. The soil here is somewhat different from that of the rest of the county, being rather lighter, both in color and composition. In general, throughout the county the drift consists of a stony clay, or till. The surface is smooth, or gently undulating. This clay has a light color for the first ten or fifteen feet, and below that depth it is apt to be blue. Stones of all kinds are disseminated through it. Some of the boulders are very large, and consist of granite. Sometimes very large boulders lie on the surface. Several such may be seen near Rose Creek village, and near Adams, and between Adams and Le Roy. At Austin a granite boulder was broken for building stone. It was at least sixteen feet long by twelve feet wide. Others were

*See the reports on Goodhue and Wabasha counties.

seen equally large in various parts of the county, and particularly on the high praries north of Brownsdale, near the county line.* Probably the average thickness of the drift for the county would be between fifty and seventy-five feet.

Ancient peat. The most interesting development in respect to the drift, in Mower county, is the existence of a bed of peat at various depths below the surface in the eastern and central portions of the county. The discovery of "coal" by Mr. Thomas Smith, S. E. ¼ sec. 12, Windom, led to some exploration of this peat bed. Mr. Smith followed it into the bank of Rose creek a distance of about seventy feet. Its greatest thickness was found to be eighteen inches. It lies at a depth of about fifty feet below the surface, having been met with in different places in that immediate vicinity. Above it is a gravelly clay, of a blue color, and the same is below it. On the top of the bed of peat were found pieces of wood, thought to be pine and cedar; but by far the most of the peaty substance consists of comminuted vegetable fiber.

This peat was met again in a shaft twenty rods further southwest, and was there about a foot thick, and about the same depth below the surface. It was met in wells two and a half or three miles northwest, at thirty-five feet below the surface. This bed of peat seems to be of considerable extent superficially. A similar deposit is struck in wells at Le Roy. Mr. J. D. Wilsey, on sec. 31, met it at twenty feet. Mr. Porter, who dug his well, describes the deposit there as largely made up of woody fiber, among which he thought he recognized hemlock bark. Several other instances of striking this buried vegetation are reported in the neighborhood of Le Roy. The clay overlying the peat bed is described as a gravelly yellow clay. Six miles northwest of Le Roy it is fifty feet under the surface, and from six to eight feet thick. It is here brownish black, and burns readily. At A. D. Parker's, near Le Roy, wood was found in digging a well. It appeared to be of cedar. At Grand Meadow wells strike black clay and muck, containing wood, at twenty-four or twenty-six feet, spoiling the water. Those that only go to the depth of twenty-two or twenty-three feet get good water. One that was fifty feet deep was so permanently bad from this cause that it was filled again. This peat has been met with at a number of places in Bennington township, and in the neighboring towns of Fillmore county. Much wood is found also in the vicinity of Lyle, at a few feet beneath the surface, in digging wells. A peat bed six feet thick was encountered on sec. 13, Pleasant Valley, at a depth of forty-five feet, underlying a compact layer of blue clay, situated in elevated land. Peat moss and sticks two inches in diameter were taken from a well at Austin, twenty feet below the surface.†

In the state of Iowa an ancient peat has slso been met with at a number of places. Dr. White describes it at Davenport, at Iowa City and in Adair county,‡ and refers its origin there to marshes that accompanied the valleys of the rivers near which the peats occur, when those rivers

*One boulder in this region was measured with the following result: North and south over the top, thirty-six feet; east and west over the top, thirty-two and a half feet; hight above the ground, eight and a half feet; with a form indicating that the major part of the stone was below the surface. A small part had been separated from the remainder, causing a fissure through the mass about ten inches in width.

†See a summary of facts respecting vegetation in the drift deposits of the Northwest in the *Proceedings of the American Association.* 1875. B., p. 43.

‡Geology of Iowa, 1870, Vol. I., p. 119.

spread wider, and flowed at higher levels. But in Mower county the peaty deposit is not confined to the valleys of streams, nor to the proximity of streams. Mower county is on one of the highest divides in the state of Minnesota, and from it flow the sources of streams toward the north, south and east. Those streams are small and never could have flooded the extent of country in which this peat is found. From all accounts it appears to be embraced between glacial deposits of gravelly clay, and it seems to mark a period of interglacial conditions when coniferous trees and peat mosses spread over the country. Peat mosses are not necessarily restricted to low, wet places. If the atmosphere be moist they will flourish on any surface, and an accumulation of good peat may take place on a bare, rocky mountain side. There are extensive marshes now existing in northern Minnesota, mainly covered with ericaceous plants, with some cedars and tamaracks, that are forming immense peat deposits. With an increase in the amount of moisture of the air such peaty accumulations would spread over much higher levels. A return of glacial conditions would bury such marshes below the deposits that are known as drift.

But little modified drift has been seen in Mower county. This, perhaps, is partly due to the fact that but little opportunity is afforded in the form of natural or artificial excavations for inspecting its actual composition. The plate of the county is wholly colored as if only the till characters of the drift exist, but a few exceptions should be mentioned. There is considerable gravel in the valley of the Upper Iowa river in Le Roy township, and in that of the Cedar in Austin and Lyle. From the south boundary of the county in sec. 33, Lyle, a flat tract consisting of gravel and sand accompanies the Cedar river northward, sometimes being about two miles wide. This plain rises from twelve to eighteen feet above the Cedar river along the north part of Lyle, and to Austin city. In the north part of Lyle a distinct terrace is seen running along the Cedar, one-half or three-fourths of a mile distant, limiting this belt of gravel and sand, and rising gradually about twenty feet above the gravel flat. This terrace gradually approaches the river toward the south, but is cut and disturbed by the entrance of Woodbury creek. The real cause of it is shown by the strike of the Devonian limestones where they appear in the banks of Cedar river, near the mouth of Woodbury creek, below which the general elevation of

the country is increased, and the contour is much more rough. North of Austin this belt of gravel and sand extends to Madison, and is sometimes partly composed of stratified clay, as shown by wells in secs. 20 and 9 in Udolpho. At Dexter the surface consists of a loamy till, and at one mile east of Dexter there is a cut by the railroad in loam showing a thickness of five or six feet, while in the adjoining low land lies a large granite boulder. In general throughout the northern part of the county the till is found from six to twelve inches beneath the surface. In the valleys of Deer and Bear creeks is found more or less stratified clay, and this has been employed, formerly, in the manufacture of red brick, on secs. 15 and 16, Frankford.

Mounds. There is a multitude of mounds on the high prairies between Grand Meadow and Le Roy, which, were it not for their great number, would be unhesitatingly pronounced artificial. They are first seen surrounding a marsh about a quarter of a mile across, about two miles and a quarter south of Grand Meadow. About twenty are here visible, rising each about two feet above the surface. Farther south they increase in number, extending three or more miles toward the south and southwest. Probably five hundred could be counted, some being five feet high. They are scattered promiscuously over the upper prairie. The surface has the appearance of having been poorly drained formerly, and was perhaps covered with shallow water till late into the summer season. These mounds have the popular reputation of being "gopher knolls." It is thought that they occur where the ground is wet and the clay near the surface. Yet, south of the region designated they do not exist, though there is no apparent difference in the prairie. The material of which they consist is the ordinary loam of the surface soil. Several of them have been removed, when near the highway, and the material hauled into the street for grading. There is no record or knowledge of any human bones or other relics having been found in them.

MATERIAL RESOURCES.

With the exception of the central high prairie portion of Mower county, it is tolerably well supplied with wood for common fuel. On the prairies referred to wood is costly. That portion of the county is thinly

settled with farmers. Along the valleys of the streams in the eastern and western portions of the county, the first settlements took place, and in those valleys are found the most of the population at this time. The principal natural wealth of the county lies in its soil and its agricultural adaptations. The people are generally farmers. The growth of the county in all respects will be primarily dependant on, and co-ordinate with, the settlement of the farming lands, and their profitable tillage. There is some water-power in the county, as at Austin, and below Austin to the county line, and at Le Roy and Ramsey, and it is well improved in the erection of flouring mills. Mower county contains no peat, and cannot hope for coal. The rocks that underlie the county cannot be depended on for producing anything but building stone and quicklime. Of the former some of the limestone would produce a good marble, if properly handled. That is the case particularly at Le Roy. For making quicklime there is ample opportunity. The only difficulty will be a competition with other localities from which transportation is light, that possess cheaper fuel for calcination. Red brick can be made at almost any place in the county. This has been demonstrated at Austin, Lansing, Le Roy and Frankford. At present there is no great demand for brick, and several establishments that were started have suspended operations.

The Mower county court house, just finished, is one of the finest in the state. It is built of red pressed-brick from St. Louis, but red brick from Austin were used in the inner walls. The outside basement walls are of dimension rock from Mankato, but the inner walls and general foundation are of the stone quarried at Austin. The steps leading to the front entrance are of the pinkish Kasota stone. The porch, with its carved capitals and columns, is of gray sandstone from Berea, Ohio. All the window tops and and the cap and sill courses are also of the Berea sandrock. The cornice and frieze, and the brackets, are of galvanized iron. The Masonic block, at Austin, is also trimmed with the Ohio stone.

Mr. L. G. Basford's residence has window-caps cut from the Austin stone, now standing fourteen years (1883). They are in good preservation, but are covered with paint. In other places in the city this rock is breaking up under the weather, especially in exposed steps and sills.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

DODGE COUNTY.

BY M. W. HARRINGTON.

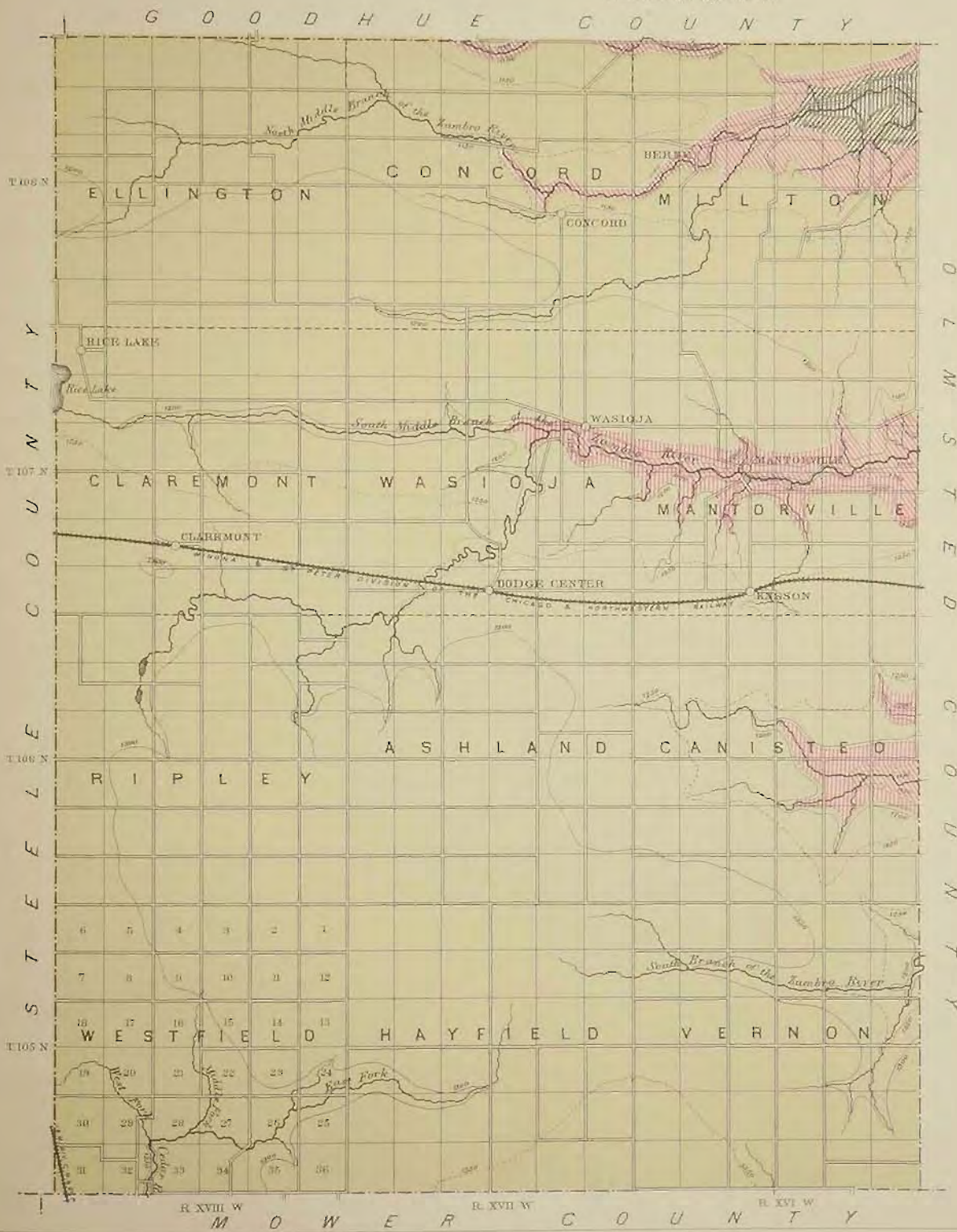
Explanation.

Quaternary — Till, smooth and undulating

Lower Silurian — Hudson River shales and limestone (including Galena); Trenton limestone

Cambrian — St. Peter Sandstone; Shakopee limestone

Contour lines are drawn approximately for each 50 feet above the sea.



Julius Bien & Co. lith.

CHAPTER IX.

THE GEOLOGY OF DODGE COUNTY.

BY M. W. HARRINGTON.

Situation and area. This county occupies the angle formed by the boundaries of the two last described, being west of Olmsted and north of Mower. Its form is that of a rectangle, being four towns long north and south, and three in width east and west. Its total area is 438.65 square miles, or 280,738.90 acres, of which 279,956.47 are land, and 782.43 are water, according to the measurements of the original survey by the United States surveyors, on record in the office of the State Auditor at St. Paul.

SURFACE FEATURES.

Natural drainage. The surface waters leave the county for the most part toward the east and northeast by means of the branches of the Zumbro river. The largest of these is the south branch of the middle fork of the Zumbro, which rises in Rice lake, on the western border of the county, and flows eastward through nearly the central portion of the county. The north branch of the same stream has its source in the wet prairies in the northwest corner of the county, and flows nearly eastward also. The south branch of the Zumbro reaches this county by two small streams which have their sources in the southeastern part. The upper tributaries of the Cedar river, known as the west, middle and east forks, rise in Westfield and Hayfield townships, in the southwestern corner of the county. These sources of the Cedar consist of a series of shallow lagoons which during the summer and autumn are not connected visibly by water currents. Lying in the broad depressions of the high prairies, they act as

basins to receive the drainage from a large tract of country, and when they become full discharge successively into each other until their volume is sufficient to maintain a continuous stream. The water-shed between the sources of the Zumbro and the Cedar is very broad and flat, and from its summit the horizon fades out before the beholder in the dim, blue distance so gradually, that unless the air be clear it is difficult to distinguish it either to the north, south or west. This divide consists immediately of drift, as indicated by large boulders along the shallow drainage lines, and by the excavations for wells.

The fall of all the streams is inconsiderable in all parts of the county, but greater in the northern part than in the southern.

Water-power. The only improved water-power in the county is found on the middle and north forks of the Zumbro river. The following list shows the location and manner of improvement of these powers:

Mills.	Owner.	Location.	Stream.	Feet of head.	Run of stone.	Kind of mill.
Wasioja.....	A. Mason & Son...	Wasioja village....	Middle fork....	9	4	Custom and flour.
Blake's....	J. D. Blake.....	Sec. 13, Wasioja...	Middle fork....	12	4	Flouring.
Mantorville.	Adams & Kneeland	Mantorville village	Middle fork ...	10 7	3	Custom.
Rockton....	John Bradford....	22, Mantorville....	Middle fork....	8	2	Custom and flour.
Agawam....	Chase & Swaringan	13, Mantorville....	Middle fork....	12	2	Flouring.
Eagle Valley	J. Gordon..	15, Concord.....	North fork.....	12	2	Custom.
Buchanan...	Widow Irish.....	Buchanan village .	North fork.....	10	....	Saw mill.
Milton.	James Elias..	9, Milton.....	North fork. ...	8	2	Custom.

Of the above mills that at Mantorville has two powers, one being about a hundred and ten rods above the other. There is an unimproved mill privilege at Concord.

The south middle branch of the Zumbro rises in Rice lake, which also has a natural outlet toward the west into Straight river, through Maple creek. In order that the mills on the eastward-flowing stream should have as much water as possible, the western outlet was cut off. Still the supply is so uncertain that the mills are compelled to stop some years during several months in the winter season. The water in the north middle branch is still more unreliable.

Topography. The surface is but little diversified. The southern and southwestern portions of the county are an undulating prairie, with no visible rock exposure, sometimes marshy, and but thinly settled. On some of these high prairies are frequently seen large quantities of boulders. They seem to prevail in the lower spots, and especially in boggy surfaces, yet are not wanting on the upland prairies. Some are twenty-five or thirty feet long, with corresponding width and hight. They are found all the way from a few miles south of Kasson to the Mower county line.* They constitute the most marked natural exception to the monotonous features

*See the Mower county report.

Elevations. Trees and shrubs.]

of the prairies. The valleys in the northeastern part of the county are from one to two hundred feet below the average level. They are sometimes precipitous and rocky, but not generally. About in the center of the county these streams pass from the drift deposits onto the rocky structure. Above this point their valleys are shallow and broad, and below it they change rather rapidly to the features that prevail, but more characteristically, in the "driftless area", and become narrow and rock-bound.

Elevations. The townships of Hayfield, Ripley and Ashland rise over thirteen hundred feet above the ocean. The valley of the north middle branch of the Zumbro descends from twelve hundred feet to slightly less than one thousand feet above the sea in crossing the county. The south middle branch descends from about twelve hundred feet to ten hundred and fifty feet in crossing the county. From the contour-lines of the map (plate 13) the townships have the following estimated average elevation, viz: Westfield, 1300 feet above the sea; Hayfield, 1340; Vernon, 1300; Ripley, 1310; Ashland, 1310; Canisteo, 1260; Claremont, 1250; Wasioja, 1225; Mantorville, 1190; Ellington, 1200; Concord, 1175, and Milton, 1140. This gives an average for the county of about 1250 feet above the sea.

According to the engineers of the Winona and St. Peter division of the Chicago and Northwestern railway, the elevation of Byron, in Olmsted county, is 1250 feet above the ocean, Kasson 1252 ft., Dodge Center 1288 ft., Claremont 1280 ft., and Havana, in Steele county, 1246 ft.

Timber, trees and shrubs. Along the streams in the eastern portion of the county is found considerable heavy timber, but the most of the county is natural grassland or prairie. In addition to the woody species named in the Olmsted county report, the following, not observed there, occur in Dodge county, and probably also others:

Menispermum Canadense, *L.* Moonseed.
Ceanothus Americanus, *L.* New Jersey tea.
Cratægus coccinea, *L.* Scarlet-fruited thorn.
Cr. Crus-galli, *L.* Cockspur thorn.
Ribes Cynosbati, *L.* Wild gooseberry.
Cornus circinata, *L'Her.* Large-leaved dogwood. Found in cold woods and on bluffs.
Fraxinus viridis, *Michx.* Green ash.
Celtis occidentalis, *L.* Sugarberry.
Ostrya Virginica, *Willd.* Hop-hornbeam.
Betula lutea, *Michx. f.* Yellow birch.
Pinus Strobus, *L.* White pine. A few straggling specimens were seen in Olmsted county. There is a grove of the trees near Mantorville.
Abies balsamea, *Marshall.* Balsam fir. With the preceding.
Juniperus communis, *L.* Common juniper.
J. Virginiana, *L.* Red cedar.

THE GEOLOGICAL STRUCTURE OF DODGE COUNTY.

The underlying rocks can only be seen in the valleys of the streams in the northeastern portion of the county. Canisteo, Mantorville, Milton, Concord and Wasioja townships include all the rocky outcrops. Over the remaining seven townships the drift conceals every feature of the rock below. All the evidence that there is indicates that to some extent, at least, the rock so covered is Cretaceous, but no facts of observation can be cited to demonstrate this.

The Shakopee limestone is found in the bottom of the valley of the north branch of the Zumbro but a short distance east of the county line, and the characteristic arrangement of the bluffs, indicating that formation, enters the county about two miles and a half. The rock has not actually been seen in Dodge county, although the overlying St. Peter sandstone appears in several places. It is on the strength of this evidence that the Shakopee limestone is shown on the accompanying map as forming the floor of the valley in Milton township.

St. Peter sandstone. Surrounding this valley is the bluffy outcrop of this sandstone. It is sometimes seen in digging wells or is cut by the grading for the highway. It preserves its characters as a white, friable sandstone, growing reddish and attaining more firmness when exposed to the air.

The Trenton limestone comprises the remaining exposures along this stream. In descending the stream everything is covered by drift until reaching the vicinity of the Eagle Valley mills, sec. 15, Concord. Here a rock in rather thin layers is quarried, but without affording any good exposure of the strata. Two miles farther down the stream is a quarry at Concord, in the south bank N. W. $\frac{1}{4}$ sec. 23, with the following

Descending section at Concord.

1.	Black loam and reddish clay	4 ft.
2.	Rubble stone	2½ ft.
3.	Dolomitic rock, yellow, with fine reddish lines; layers two to eight inches thick	3 ft.
4.	Bluish stone, less dolomitic, in even beds from one to two feet thick	3 ft.
5.	Bluish stone, not dolomitic, in thin layers	1 ft.
6.	Heavy layers of bluish stone	3½ ft.
	Total	17 ft.

Below this is a compact limestone, not well exposed. It is not dolomitic and is good for burning.

At the saw-mill near the middle of sec. 17, Milton, the road passes around an exposure of rock. Here are about ten feet of shaly limestone and blue clay. A fine specimen of *Receptaculites* lay in the wheel-track of the road, and had been considerably marred. Many other incomplete specimens were found.

An eighth of a mile below this saw-mill (still in sec. 17, Milton), is an irregular bluff on the south side of the stream. It is concealed by debris, bushes, etc., and not very accessible. The following measurements and observations were obtained with as much accuracy as circumstances would admit. They are taken from above:

Section on sec. 17, Milton.

1. Yellowish limestone in thin layers..... 10 ft.
2. Compact aluminous layers, 4 to 6 inches..... 1 ft.
3. Shale, limestone, and blue clay in alternate layers, usually thin..... 15 ft.

Below, passing under the debris and probably occupying the present river bed is a thick stratum of compact limestone, with a depth of upwards of twenty feet. *Receptaculites* is abundant in the rock.

As might be anticipated from the structure of the rock, living springs are abundant along these bluffs. One very fine one, the size of one's arm pours out from the rock just above the saw-mill, at a distance of twenty feet above the water of the stream. Here these springs are almost equal in number in bluffs facing north or south, betraying the absence ot dip at this point in either of those directions.

Other small exposures of Trenton rock were seen in the road in several places within the Trenton area as marked on the accompanying map, as at sections 19 and 30 of Milton township, and in sections 12, 13 and 14 of Mantorville. The lower parts of the exposures at Mantorville and Wasioja are, in all probability, Trenton; but as it is impracticable to tell where this rock begins and the rock above ceases, these exposures will be described under the Galena. The Trenton can also be traced into this county from Olmsted, in sec. 14, Canisteo, and from Goodhue along the north fork of the middle branch of the Zumbro, near the north county line.

The Galena limestone is found cropping out along the south middle branch of the Zumbro. In descending this stream no rock is found until

reaching sec. 14, Wasioja. The first important quarry is that of Thomas Arnold, on the north bank of the stream, in sec. 13. At the top of the exposed wall is a layer of five feet of rubble stone. Below this are thirty feet of dolomitic, sparry stone, yellow when weathered, but blue within. It is in evenly bedded layers from six inches to three feet thick. It works smoothly and is soft, without flint. Near the bottom the rock is gray when weathered.

A few rods below this, on the same side of the stream, are the lime-kilns of James Paul, two in number. This is in the village of Wasioja, in sec. 13. The rock, of which he has eight or ten feet exposed close by, is yellow and in thin, rather irregular, fragments. It is in all probability Galena. Mr. Paul obtains from this a lime of a light yellow color. He burns about 840 barrels per year, for which he obtains $1.00 per barrel. He uses for this eighty-six cords of wood, for which he pays $4.00 per cord. Mr. Paul praises his lime highly, and it is acknowledged by all to be good for laying stone. It is, however, generally said to be slow in slacking, and not strong. At Blake's mill, on the eastern edge of sec. 13, of Wasioja is an exposure of about thirty feet of rock where materials have been obtained for the mill and dam. The upper five feet are of broken rubble stone. The remainder is in solid, even beds, six inches to three feet thick. The stone is a limestone, yellow, dolomitic, compact, coarse-grained.

About half a mile above Mantorville, in section 17, of Mantorville township, is a natural exposure of about forty feet of rock, on the north bank. The upper twenty feet are composed of a compact rock in thick beds, yellow in color, wearing away very evenly by weathering, in a castellated manner. Below it the rock wears much more unevenly and is grayish. Between the two lies a thin soft layer which was not accessible. It wears out much more rapidly than the other rocks. It is probably a clay-shale. About twenty yards from this place is a fine spring, always flowing. It is caused by a layer of green shale lying just below it.

In the bed of the stream, just below the first dam at Mantorville, sec. 20, is a compact, dark limestone, in thin beds and not dolomitic. Just below the village of Mantorville are the quarries owned by H. Hook, P. Mantor, A. Doig and others.

Section at Hook's quarry, Mantorville.

1.	Loose fragments,	4 ft.
2.	Beds from six to twenty inches each, of vesicular magnesian limestone, almost free from iron, very much used formerly for all kinds of construction,	30 ft. 10 in.
3.	Thin, slaty, argillo-magnesian beds,	1 ft. 6 in.
4.	Good heavy beds of magnesian limestone, same as No. 2.	11 ft. 6 in.
5.	Shaly and thinner beds, seen,	5 ft,
	NOTE—Where these beds are weathered out, a white deposit is accumulated on the slope below, having much the taste of lime, yet it may consist of alumina and lime. On the face of the rocks the coating is bitter and sour, tasting somewhat like Epsom salt.	
6.	Heavy magnesian layers, of a buff color, with considerable shale	20 ft.
	Total	63 ft. 10 in.

The stone taken from the quarries at Mantorville is highly prized, and has been placed in some important buildings.* It is evenly bedded and can be got out in good shape. It has but little grit or flint to take off the edge of tools, working easily and cheaply. It hardens after exposure, and has a pleasant, light yellow color, or when from deep within the quarry shows a light blue color. It is rarely affected by spots of iron pyrites.

Section at Mantor's quarry.

1.	Loose material, with broken rubble stone	2 ft.
2.	Light yellow rock, in layers three inches thick	1 ft.
3.	Yellow dolomitic rock, in thick beds	4 ft. 6 in
4.	Shaly, yellowish rock, including a layer of two inches of an uncemented, rather fine gravel containing numerous black quartzyte pebbles	6 in.
5.	Yellow, dolomitic rock, in thick beds	4 ft.
	Total	12 ft.

In the bed of the race at the second dam at Mantorville, a hundred and ten rods below the mill, is a fossiliferous green shale. These sections, and that which follows, show that the transition from the Trenton to the Galena was gradual, the occurrence of the buff and magnesian layers marking those changes favorable for the deposition of the Galena limestone which preceded the full introduction of that epoch.

Section at Rockton mills, sec. 22, Mantorville.

1.	Slope from the summit of the bluff (hid) estimated	40 ft.
2.	Magnesian layers, buff, much shattered	4 ft. 6 in.
3.	Shale	2 ft. 6 in.
4.	Good layers of vesicular, buff, magnesian stone, with some argillaceous patches	11 ft.
5.	Argillo-magnesian limestone, weathering into rather thin beds	3 ft.
6.	Vesicular, buff, magnesian limestone. In one bed	10 in.
7.	Shale and shaly limestone	2 ft. 2 in.

*Compare the chapter on building stones, p. 167.

8.	Beds of argillaceous limestone, each of about eight inches and separated by shale beds, each of the latter being about two inches, containing *Receptaculites*	5 ft. 2 in.
9.	Shale	4 in.
10.	Vesicular limestone, argillo-magnesian, in one bed	9 in.
11.	Shaly and calcareous beds (thin)	8 in.
12.	Crystalline beds of a gray color, weathering buff, one bed	1 ft. 7 in.
13.	Shale and shaly limestone	1 ft. 4 in.
14.	Shale	8 in.
15.	Argillo-magnesian limestone, some parts crystalline and calcareous only; in three beds	6 ft. 4 in.
16.	Shale	4 in
17.	Argillo-magnesian; one bed	10 in.
18.	Shale	1 ft. 2 in.
19.	Hard crystalline limestone of a gray color with some cavities and specimens of *Receptaculites*	2 ft. 2 in.
20.	Shale	6 in.
21.	Argillo-magnesian, one bed; showing *Chætetes* and fucoids of the Trenton epoch	1 ft. 6 in.
22.	An interval, not well seen, of beds of greenish-blue shale and argillaceous limestone, each varying from eight to twelve inches, showing abundant fossils of the Trenton	16 ft.
23.	Blue, earthy limestone; under water and not well seen	6 in
	Total	103 ft. 10 in.

In Canisteo township, due south from Kasson, is an exposure of the Galena limestone at the crossing of one of the branches of the Zumbro, and along the stream for some distance below. It appears in heavy, coarse, cavernous layers eight to sixteen inches thick, of a buff color, and without apparent fossils, and has been slightly opened by quarrying.

Rock that resembles the Galena is used at Concord for building stone, and by the farmers for foundations between Concord and Mantorville.

THE DRIFT.

This covers nearly the whole county. Boulders are abundant and sometimes very large, as has been stated under the head of *topography*. A stony blue clay underlies the southern and western portions of the county, and its tenacious and impervious character is the cause of numerous marshes in that part of the county. This clay is uniformly met in digging wells, at the depth of from ten to thirty feet, and sometimes it contains logs and other vegetation. While it is essentially a drift-clay, probably, in nearly all cases it is augmented by the disrupted and disseminated shaly beds of the Cretaceous, which has added largely to the thickness of the drift-clay in other counties. These characters fade out toward the northeast, in Dodge county, so that the drift-clay loses its blue color, and all the materials of the drift are affected by yellow loam that there takes the place of the drift-clay.

Drift.]

On the railroad between secs. 32 and 33, of Wasioja, the water washed out a ditch to a considerable depth so that the following section could be seen:

Black loam	2 ft.
Yellow, sandy clay, with some small pebbles below	6 ft.
Alternations of thin, ferruginous, sandy films and black, or yellowish, sandy clay	4 ft.
Total	12 ft.

In the bottom of the ditch was a bluish quartzyte boulder, fifteen inches across, and six inches thick, worn off smoothly on one side by glacial action. The smooth side was polished, but scratched.

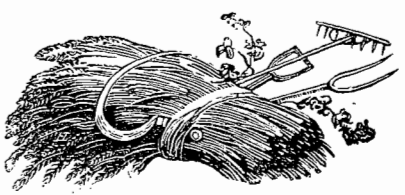
At the crossing of the railroad over a stream a similar section amounting to fifteen feet was seen, except that the bottom clay was dark blue and without the ferruginous films, and contained numerous drift-pebbles, and a piece of Galena limestone.

In some of the railroad cuttings in Wasioja, some ferruginous concretions of small size and much decayed were seen, with numerous fragments of Galena limestone, and a solitary piece of argillyte.

Two miles east of Kasson Mr. Watson Houston found a stick twenty-five feet beneath the surface, two feet long and three and a half inches in diameter. It was like Norway pine or tamarack, with loose texture and coarse annual growths.

Brick are made from the surface loam at Dodge Center, and three miles east of Dodge Center. At Kasson are made brick and drain tiles, for which, however, the clay is obtained at Mantorville.

Lime is burnt in sec. 17, Milton, from the strata of the Trenton, and on sec. 10, Milton, from a surface deposit of travertine.



CHAPTER X.

THE GEOLOGY OF FREEBORN COUNTY.

BY N. H. WINCHELL.

Situation and area. This is one of the southern border counties, and lies very near the center of the southern boundary of the state. It embraces five government towns east and west and four north and south in the form of a rectangle, making an area of 701.94 square miles, or 449,242.53 acres, after deducting the areas covered by water, the latter being 13,271.87.

SURFACE FEATURES.

Natural drainage. With the exception of Freeborn, Hartland and Carlston townships, the surface drainage is toward the south and southeast. The county embraces the headwaters of the Shell Rock and Cedar rivers of Iowa, and those of the Cobb river which joins the Minnesota toward the north. Hence it lies on the watershed between two great drainage slopes. For the same reason none of its streams are large, the Shell Rock, where it leaves the state being its largest. The streams have not much fall, but afford some water-power, which has been improved in the construction of flouring mills. Such are found at Albert Lea and Twin Lakes. In these cases the body of water confined in the upper lake serves as the water-head and reservoir, the mills being constructed near their outlets. There is also an available water-power near Shell Rock village, but its use would cause the flooding of a large body of land adjoining the river.

Topography. The surface of the county,* although having no remarkable changes of general contour, yet is marked by two belts or areas of rolling prairie which cross it from north to south, and is more or less covered with sparse oaks and oak bushes. The rolling tracts mentioned differ

*Some notes on the topography and on wells in this county are derived from Mr. Upham.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

FREEBORN COUNTY

BY N H WINCHELL

considerably in area but are alike in all essential features. The eastern belt of rolling land passes through sections 5, 9, 16, 21, 28, 33, in Newry township; through sections 4, 9, 16, 20, 30 and 31 of Moscow; through sections 6, 7, 18, part of 17, 19 and 30, of Oakland; section 36 of Hayward, and diagonally southwestward through Shell Rock, leaving the state east of Shell Rock river. In Shell Rock it is less marked, but a rolling surface is found along the valley of the Shell Rock river, accompanied by timber, and through sections 2, 10, 15, 16, 21, 22, 27, 28, and 33. This belt varies from one to three miles in width, and the short ridges and conical hills of which it consists rise from twenty-five to sixty feet above the smooth prairies adjoining on either side, their most characteristic development being in Newry, in section 16.

The other area of rolling surface occupies much of the central portion of the county, and varies from four to twelve miles in width, its most marked development being in secs. 1 and 2 in Pickerel Lake township. It covers nearly all of Bath, Bancroft and Albert Lea, and the northwestern third of Freeman. It also embraces the southeastern third of Hartland, the eastern three-quarters of Manchester, nearly all of Pickerel Lake and Nunda, the southeastern corner of Alden and a belt about two miles wide through the west part of Mansfield. It extends westward and northwestward in Faribault county nearly to Lura. The hills that diversify the surface in this part of Freeborn county are generally formed by smooth swells and gentle depressions in the gravelly clay, or hardpan of that part of the state, but sometimes they are abrupt and and stony, rising from seventy-five to one hundred feet. The valleys between are frequently wet, and contain much peat. The material of which the hills consist is the drift-sheet of the Northwest, mainly a gravelly clay, but sometimes gravel and sand in oblique stratification. The rest of the county is either flat or moderately undulating. The smoothest portions are the eastern two-thirds of Oakland, the greater part of London and the western half or two-thirds of Freeborn and Carlston. The marsh occupying sec. 12, Hayward, and parts of the adjoining sections, is commonly called the "big slough." The maximum depth of Freeborn lake is reported to be twenty-five feet, and of Geneva lake fifteen to twenty feet. The town of Albert Lea is forty-two feet above lake Albert Lea. The stream flowing from Fountain

lake into lake Albert Lea falls eight and a half feet, and is the site of a dam and mills.

The plats of the United States surveyors, on file in the Register's office at Albert Lea, indicate considerably more area covered with timber, or as "oak openings," when the county was surveyed by them, than is now the case. The following minutes are based on an examination of their plats, and will give a pretty correct idea of the distribution of the oak openings and the prairie tracts throughout the county.

London. The most of this township is prairie, a belt of oak openings and timber entering it from the north about three miles wide, and extending to the center, bearing off to the southeast and terminating in section 24. The magnetic variation throughout the town was, when surveyed (1854), from 8° 20′ to 10° 42′, the greatest being in secs. 33 and 34.

Oakland. A little more than a half of this township consists of oak openings, an area in the eastern half only being prairie, with a small patch also in sec. 31. Two large sloughs cross the town, one through sections 30, 31 and 32, and the other through sections 4, 5, 8, 7 and 18. Magnetic variation about 9°, varying from 8° 12′ to 10° 8′, in 1854.

Moscow. Nearly the whole of this township is taken up with oak openings and marshes. Turtle creek crosses it from N. W. to S. E. A large portion of the northern half of the town is a floating marsh, containing a great quantity of peat. Magnetic variation from 9° 20′ to 10° 20′ in 1854.

Newry. There is a small patch of prairie in the northeast part of this town, secs. 1, 12, 13 and 24, and a small area in secs. 20 and 21. There is another in the N. W. corner, embracing sections 6 and 7, and parts of 5, 8 and 18. The rest is openings and marsh, particularly marsh in the S. W. corner. Magnetic variation 8° 20′ to 9° 40′, in 1854.

Shell Rock. A belt about 1½ miles wide along the west side of this town, accompanying the Shell Rock river, constitutes the only openings or timbered portion, the rest being prairie. This district also comprises some marsh, viz.: secs. 19 and 31. The first house in the county was built in sec 33 in this town, in the S. W. quarter. Magnetic variation 8° 45′ to 10° 15′, in 1854.

Hayward. A wide belt of prairie occupies about two-thirds of this town, running north and south through the center. On the west of this is a rolling tract embracing a portion of lake Albert Lea and some tributary marshes, while on the east a large marsh covers sections 12 and 14, and portions of 13, 11, 15, 22 and 23. There is also a prairie tract in sec. 1.

Riceland. This township is about equally divided between prairie, openings and marsh the first being in the south central portion, the second in the northwest and central, bordering on Rice lake, and the marsh in the northeastern part of the town. Magnetic variation from 8° 45′ to 10° 30′.

Genera. There is but little prairie in this town, the southern portion being comprised in a large marsh which is crossed by Turtle creek, the outlet of Walnut (or Geneva) lake. The central portion is occupied by oak openings which also extend to the N. W. and W. boundaries. The prairie is in the northern and eastern portions. Magnetic variation 9° 10′ to 10° 23′, in 1854.

Freeman. This township comprises no prairie. It is mostly devoted to oak openings, but a series of marshes, drained by the tributaries of the Shell Rock, that cross it toward the S. E. take up a considerable area in the central and eastern portions. Mag. var. 9° to 10° 40′, in 1854, the greatest being in sec. 31.

Albert Lea. This township is nearly all taken up with oak openings, but a few small marshes, trending N. W. and S. E. are found in different portions. There is also a small patch of prairie in sec. 6, and another in the S. E. corner of the county. The western arm of Albert Lea lake, through which the Shell Rock river runs, is in the central and eastern part of this town and adds greatly to the variety and beauty of its natural scenery. Pickerel lake is also partly in this township. Mag. var. 8° 46′ to 10° 8′.

Bancroft. A little more than one-fourth of this township is prairie, situated in the central and southwestern portions. The rest of the town is covered with oak openings. The source of Shell Rock river is in the N. W. part of this town. Mag. var. 8° 50′ to 10° 15′, in 1854.

Bath. An area of openings comprising about half of this town in the central and eastern

portions is nearly surrounded by a belt of prairie. Small marshes are scattered through the town. Mag. var. 8° 45′ to 10° 35′, in 1854.

Nunda. This town is also mostly openings, but an area of prairie occurs on sections 4, 5, 9 and 3; another lies southwest of Bear lake. Considerable marsh land is embraced within the area of openings. Mag. var. in 1854 10° 5′ to 12° 15′, the latter in section 31.

Pickerel Lake. The west half of this township is prairie, and the eastern is devoted to openings with lakes and marshes. Mag. var. 9° 45′ to 11° 50′ in 1854.

Manchester. About one-half of this town is prairie, the remainder being oak openings. The prairie lies in the northwestern and southern portions. Small marshes occur both in the prairies and openings. Mag. var. 10° to 12° 15′ in 1854.

Hartland. This town is almost entirely composed of prairie, the only timber being about Mule or Le Sueur lake, and in the southern portions of sections 34, 35 and 36. There is not much marsh in the town. Mag. var. 9° 45′ to 12° 25′ (1854).

Mansfield. This town is nearly all prairie, a small patch of oak openings occurring in sections 3, 10 and 15. The northwest part of the township is rolling and the southeast is level and wet with marshes. Mag. var. 11° 30′ to 13° 40′ (1858).

Alden. This town is all prairie, with scattered small marshes. Mag. var. 11° 27′ to 13° 15′ (1854).

Carlston. This town is all prairie except a narrow belt of sparse timber about Freeborn lake. Long narrow marshes spread irregularly over the central and eastern portions of the town. In the southeast quarter of section 36 there is also a small area of sparse timber. Mag. var. 11° 13′ to 13° (1854).

Freeborn. In this town there is a little sparse timber about the north ends of Freeborn and Spicer lakes, and a little adjoining Spicer lake on the east. There are also some openings in section 26, where the arms of the marsh protect the timber from the prairie fires. The rest is of prairie, with spreading marshes. Mag. var. (1854) 11° 55′ to 12° 50′.

North and west of Albert Lea is a very broken and rolling surface of sparse timber. This tract consists of bold hills and deep valleys wrought in the common drift of the country. On some of these hills are granitic boulders, but the country generally does not show many boulders. The drift is usually in this broken tract, a gravelly clay. In some of the road cuts for grading a gravel is found containing a good deal of limestone.

A great many of the marshes of the county are surrounded with tracts of oak openings, a fact which indicates that the marshes serve as barriers to the prairie fires. Such marshes are really filled with water and quake with a heavy peat deposit on being trod on. They are very different from those of counties farther west, as in Nobles county, which in the summer are apt to become dried, and are annually clothed with a growth of coarse grass which feeds the fires that pass over the country in the fall. As a general rule but little or no grass grows on a good peat marsh.

The contour of the county is further exemplified by the following elevations obtained from lines run for railroad surveys:

Elevations taken from a preliminary survey made in July, 1870, *through Freeborn county, Minnesota, by* WM. MORIN.

Commencing on the state line (south) 930 feet east of the quarter stake on the south side of sec. 32, T. **101**, R. **20**; thence north to Glenville on sec 6, T. **101**, R. **20**; thence north 40° west to Albert Lea on sec. 8, T. **102**, R. **21**; thence north 40° east to Geneva on sec. 8, T. **104**, R. **20**, and thence north to the Steele county line.

	Above ocean. Feet.
Station No. 1, at point 930 ft. east of quarter stake on sec. 32, T. **101**, R. **20**,	1212
Station No. 100,	1221
Station No. 190,	1199
Station No. 199+10. Water in Shell Rock river, east bank,	1197
Station No. 200+80. Water in Shell Rock River, west bank,	1197
Station No. 202,	1212
Station No. 300. Glenville (town plat)	1221

Station No. 494. Summit between Glenville and Albert Lea,	11 miles.	1313
Station No. 654. Albert Lea (town plat),		1243
Lake Albert Lea,		1201
Station 1064. Summit at Clark's Grove,		1314
Geneva lake (or Walnut lake)		1214
Station No. 1330, at Steele county line, sec. 5, T. **104**, R. **20**,		1206

Elevations obtained of George B. Woodworth, assistant engineer of the Southern Minnesota railroad, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Ramsey, crossing Iowa and Minn. div. of Chicago, Milwaukee and St. Paul railway,	103.1	1214
Depression, grade,	107.7	1197
Oakland,	109.9	1265
Summit, grade,	113.8	1270
Depression, grade,	117.6	1241
Hayward,	118.0	1248
Summit, grade,	121.5	1263
Depression, grade,	124.2	1206
Albert Lea,	124.6	1221
Burlington, Cedar Rapids and Northern crossing.	124.7	1220
Summit, grade,	128.9	1323
Armstrong,	129.8	1270
Summit, grade,	133.5	1317
Alden,	135.2	1261
Dood's switch,	139.7	1189
Wells,	144.4	1153

Elevations on the Minneapolis and St. Louis railway, from Robert Angst, assistant engineer.

	Miles from Minneapolis.	Feet above the sea.
Hartland,	94.9	1247
Manchester,	100.9	1258
Albert Lea,	108.0	1224
Twin Lakes,	115.0	1255
Norman,	121.4	1279

Average elevation of the county. The most of the county is more than 1,200 feet above the sea, the range being between 1,100 and 1,400, the average elevation for the county being about 1,250 feet. The average elevation of the different townships is about as follows, estimated from the contour lines: Newry, 1,275 feet above the sea; Moscow, 1,250; Oakland, 1,260; London, 1,225; Geneva, 1,240; Riceland, 1,240; Hayward, 1,240; Shell Rock, 1,260; Bath, 1,280; Bancroft, 1,290; Albert Lea, 1,250; Freeman, 1,250; Hartland, 1,225; Manchester, 1,275; Pickerel Lake, 1,290; Nunda, 1,275; Freeborn, 1,175; Carlston, 1,210; Alden, 1,260; Mansfield, 1,275. The mean elevation of Freeborn county, derived from these figures, is approximately 1,250 feet above the sea.

Soil. Throughout the county the soil depends on the nature of the drift combined with the various modifying local circumstances. There is nothing in the county that can properly be designated a *limestone soil,* or a *sandstone soil.* The materials of which it is composed have been transported perhaps several hundred miles, and are so abundantly and universally spread over the underlying rock that they receive no influence from it. The sub-soil is a gravelly clay, and in much of the county that also constitutes the surface soil. In low ground this of course is disguised by a

Soil. Trees and shrubs.]

wash from the higher ground, causing, sometimes, a loam and, sometimes, a tough, fine clay, the latter particularly in those tracts that are subject to inundation by standing water. On an undulating prairie, with a close clay, or clayey subsoil, such low spots are apt to have a black, rich loam or clayey loam, the color being derived from the annual prairie fires that leave charred grass and other vegetation to mingle with the soil. The same takes place on wide tracts of flat prairie. In these there may be but rarely a stone of any kind—indeed that is usually the case—but below the immediate surface, a foot or eighteen inches, a gravelly clay is always met with. This at first doubtless formed the soil, the disintegrating forces of frost, rain and wind, combined with the calcining effects of the prairie fires, having reduced the stones and gravel to powder, leaving a finely pulverized substance for a surface soil. In a rolling tract of country, while the low ground is being filled slowly with the wash from the hills, and furnished with a fine surface soil, the hills are left covered with a coarse and stony surface soil. For that reason a great many boulders are sometimes seen on the tops of drift knolls. Along streams, and about the shores of lakes, the action of the water has carried away the clay of the soil and often eaten into the original drift, letting the stones and boulders tumble down to the bottom of the bank, where they are often very numerous. Along streams they are sometimes again covered with alluvium—indeed are apt to be—but along the shores of lakes they are kept near the beach line by the action of winter ice. After a lapse of time sufficient, the banks themselves become rounded off, and finally turfed over or covered with trees. Thus lakes sometimes extend their limits laterally, but slowly become shallower.

This county is furnished with a number of very beautiful lakes. These are generally in the midst of a rolling country, and some of their banks are high.

Timber. In the survey of the county the following species of trees and shrubs were noticed growing native:

Quercus macrocarpa, *Michx.* Bur oak.
Populus tremuloides, *Michx.* Aspen.
Ulmus Americana, *L.* (pl. Clayt.), *Willd.* White elm.
Pirus coronaria, *L.* American crab-apple.
Juglans nigra, *L.* Black walnut.
Vitis cordifolia, *Michx.* Frost grape.
Prunus Americana, *Marshall.* Wild plum.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Prunus serotina, *Ehr.* Black cherry.
Carya amara, *Nutt.* Bitternut.
Corylus Americana, *Walt.* Hazelnut.
Celastrus scandens, *L.* Climbing bitter-sweet.
Fraxinus Americana, *L.* White ash.

Juglans cinerea, *L.* Butternut.
Rubus strigosus, *Michx.* Red raspberry.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.
Xanthoxylum Americanum, *Mill.* Prickly ash.
Salix. Different species.
Cratægus coccinea, *L.* Thorn.
Acer saccharinum, *Wang.* Sugar maple.
Acer dasycarpum, *Ehr.* Soft maple.
Ulmus fulva, *Mich.* Slippery elm.
Viburnum Opulus, *L.* High-bush cranberry.
Carya alba, *Nutt.* Shagbark hickory.
Rhus glabra, *L.* Smooth sumach.
Rosa blanda, *Ait.* Rose.
Tilia Americana, *L.* Bass.
Cornus. Different species.
Ribes Cynosbati, *L.* Prickly gooseberry.
Celtis occidentalis, *L.* Hackberry.
Populus monilifera, *Ait.* Cottonwood.
Cratægus Crus-galli, *L.* Cockspur thorn.
Fraxinus sambucifolia, *Lam.* Black ash.
Prunus Virginiana, *L.* Choke cherry.

The last is seen on land of M. B. Bullis, in Moscow township, near the county line.—A. A. HARWOOD.

Besides the foregoing, the following list embraces trees that are frequently seen in cultivation in Freeborn county.

Juniperus Virginiana, *L.* Red cedar.
Populus balsamifera, *L.* var. candicans, *Gray.* Balm of Gilead.
Larix Americana, *Michx.* Hackmatack.
Pirus Americana, *DC.* Mountain ash.
Populus dilatata, *Ait.* Lombardy poplar.
Robinia Pseudacacia, *L.* Locust.
Thuja occidentalis, *L.* Arbor vitæ.

THE GEOLOGICAL STRUCTURE.

There is not a natural exposure of the underlying rock in Freeborn county. Hence the details of its geological structure are wholly unknown. It is only by an examination of outcrops in Mower county and in the adjoining counties of Iowa, together with a knowledge of the general geology of that portion of the state, that anything can be known of the bed-rock of Freeborn county. In the absence of actual outcrops of rock within the county there are still some evidences of the character of the rock that underlies the county, in the nature and position of the drift materials. There is, besides, a shaft that has struck the Cretaceous in the northwestern portion of the county, in exploration for coal.

Although the drift is heavy it lies in such positions that it shows some changes in the surface of the bed-rock. It is a principle pretty well established that any sudden great alteration in the rock from hardness to softness, as from a heavy limestone layer to a layer of erosible shales, or from shales to more enduring sandstone, each stratum having a considerable thickness, is expressed in the drift by changes from a rough and rolling, more or less stony surface to a flat and nearly smooth surface, or *vice versa.* It sometimes happens that the non-outcropping line of superposition of one important formation with another, either above or below, can be traced across a wide tract of drift-covered country by following up a series of gravel knolls or ridges that accompany it, or by some similar feature of

the topography. Again the unusual frequency of any kind of rock in the drift at a certain place, especially if it be one not capable of bearing long transportation, is pretty good evidence of the proximity of the parent rock to that locality.

Applying these principles to Freeborn county, we find throughout the county a great many boulders of a hard, white, compact, magnesian limestone, many others of which have been burned for quicklime. These attracted the attention of the early settlers, and before the construction of the Southern Minnesota railroad supplied all the lime in the county. Although these boulders are capable of being transported a great distance, their great abundance points to the existence of the source of supply in the underlying bed-rock. In the drift also are frequently found pieces of lignite, or Cretaceous coal, which cannot be far transported by glacier agencies. This also indicates the existence of the Cretaceous lignites in Freeborn county. In regard to changes in the contour of the natural surface, we see an evenly flat and prairie surface in the western tier of towns, and in the southeastern part of the county, and a hilly and gravelly tract of irregular shape in the central portion. There are two ridges or divides, formed superficially of drift, that occur in the central part of the county, one north of Albert Lea, and the other south of it, separated about eleven miles, as shown by a series of elevations for a preliminary railroad survey by Wm. Morin, already mentioned. What may be their direction at points farther removed from Albert Lea it is not possible to state with certainty, but on one side they seem to trend toward the northwest. Indeed there seems to be a northwest and southeast trend to some of the surface features. Such rough surfaces, and especially the ridges of drift are more stony and gravelly than the flat portions of the county. They mark the location of great inequalities in the upper surface of the underlying rock, the exact nature of which cannot be known.

In addition to these general indications of the character of the rock of the county, the shaft sunk for coal at Freeborn reveals the presence of the Cretaceous in that portion of the county, and examinations of the nearest exposures in the neighboring county of Iowa disclose the Hamilton limestone of the Devonian age. This limestone is exactly like that found so abundantly in the form of boulders in Freeborn county. As the general direction of the drift forces was toward the south, and as the strike of the Hamilton in Iowa is toward the northwest, there is abundant reason for concluding that that formation also extends under Freeborn county. The great distance toward the northwest through which these limestone boulders can be traced with

equal abundance, is an evidence of the former extent of the Devonian rocks in that direction. The Devonian does not certainly cross the Minnesota river. Yet in McLeod county, which lies in the line of strike of the Devonian of Iowa and Freeborn county, toward the northwest, on the opposite side of the Minnesota river, the same limestone boulders are very abundant, some being so large as to have been reputed rock *in situ*, and quarried as such till exhausted. There is, in the neighborhood of Freeborn, an area of the Cretaceous, which must overlie the Silurian limestones. This Cretaceous area is believed to extend north and south across the west end of the county and to be roughly coincident with the flat and prairie portion in the western part of the county, in which case it also overlaps the Devonian.

Explorations for coal.

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

1.	Soil and subsoil, clay	15 feet.
2.	Blue clay	35 feet.
3.	"Conglomerated rock" (Had to drill)	2 in.
4.	Sand with water	5 feet.
5.	Fine clay, tough, and hard to drill, with gravel, and limestone pebbles	60 feet.
6.	Sand with water	4 in.
7.	"Slate rock" (Probably Cretaceous	7 feet.
8.	"Coal"	5 feet 4 in.
	Total depth	127 ft. 10 in.

This indication of coal induced the drilling of another well situated one hundred feet distant, toward the northeast. In this the record was as follows, given by the same authority.

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

When the drill here reached the "conglomerated rock", it was supposed to have reached the "slate rock", No. 7, of the previous section. The amount of coal in the sand of No. 4 was also enough to cause it to be taken for No. 8 of the previous section. Hence the boring was stopped; and having thus demonstrated the existence of a coal-bed, to the satisfaction of the proprietors, the enterprise was pushed further in the sinking of a shaft. In sinking this shaft water troubled the workmen so that at thirty-five feet it had to be abandoned.

Three-quarters of a mile north of these drills a shaft was sunk fifty-seven feet, but not finding the coal as expected, according to the developments of the last section above given, this exploration ceased. In this shaft the overseer reports the same strata passed through in the drift as met with in the first well drilled, but the so-called "conglomerated rock" was met at a depth of forty-five feet. The sand below the "conglomerated rock" here held no water, but was full of fine pieces of coal. Before sinking the shaft at this place a drill was made to test the strata. These being found "all right" the shaft was begun. In that drill gas was first met. It rose up in in the drill-hole, and being ignited it flamed up eight or ten feet with a roaring sound. The shaft was so near the drill-hole that it drew off the gas gradually, allowing the intermixture of more air, thus preventing rapid burning. From this place the exploration was re-directed to the first situation, where another shaft was begun. This was in search for the "lower rock", so called, or the "slate rock" supposed to overlie the "coal". Here they went through the same materials, shutting

off the water in the five-foot sand bed, and sixty feet of fine clay, when water rose so copiously from the second sand bed (No. 6 of the first section given) as to compel a cessation of the work. In this shaft were found small pieces of the same coal, all the way. These pieces had sharp corners and fresh surfaces. The total depth here was 106 feet, and the water seems to have been impregnated with the same gas as that which rose in the drill at the point three-fourths of a mile distant. Such water is also found in the well at the hotel at Freeborn. With sugar of lead it does not present the reactions for sulphuretted hydrogen, and the gas is presumed to be carburetted hydrogen.

Further exploration was undertaken in 1880. This was done by Mr. E. B. Clark, the shaft going to the depth of 144 feet. The section as reported by Mr. Clark, was found to be soil, 2 feet; yellow till, 14 feet; softer blue till, 29 feet; sand, 1 foot; gray till, harder than the yellow till, 47 feet; sand, 1 foot; gray till, 2 feet; quicksand, 44 feet, "containing at 124 feet from the surface a stratum of slate two inches thick, underlain by six inches of coal". Small fragments of lignite were found in the blue and gray till, but apparently not larger nor more numerous than are often found in this formation in wells throughout southern and western Minnesota. The remaining four feet were said to have been drilled in "slate"; but nearly all the detritus brought up was gray sand, with which was intermingled a small proportion of black slaty particles, perhaps making up a quarter of one per cent. This boring is eight rods farther east, and at a site three feet lower, than the first of those above mentioned.

This account of explorations for coal is but a repetition of what has taken place in numerous instances in Minnesota. The Cretaceous lignites have deceived a great many, and considerable expense has been needlessly incurred in fruitless search for good coal. In the early discovery of these lignites some exploration and experimentation within the limits of the state were justifiable, but after the tests that have already been made it can pretty confidently be stated that *these lignites are at present of no known economical value.* This, not in ignorance of the fact that they will burn, or that they contain, in some proportion, all the valuable ingredients that characterize coal and carbonaceous shales, but in the light of the competing prices of other fuels, the cost of mining them, and the comparative inferiority of the lignites themselves.

The drift. Till. This deposit covers the entire county and conceals the rock from sight. It consists of the usual ingredients, but varies with the general character of the surface. In rolling tracts it is very stony and has much more gravel. In flat tracts it is clayey. It everywhere contains a great many boulders, and these are shown abundantly along the beaches of the numerous lakes of the county. The frequency of limestone boulders, and their significance, have already been mentioned. Thousands of bushels of lime have been made from such loose boulder masses, mainly gathered about the shores of the lakes. The two belts of prominently rolling till described on page 377 are parts of a series of terminal moraines that mark the boundary of the ice-sheet in the last glacial epoch.* The average thickness of the drift in Freeborn county does not vary much probably from one hundred feet.

Gravel and sand. In general the drift of Freeborn county is glacier hardpan or till. Yet in some places the upper portion is gravel and sand, showing all the effects of running water in violent currents, such as oblique bedding and sudden transitions from one material to another.

*For a description of the mode of formation of the moraines, see the report of Waseca county.

In a gravel bank at Albert Lea, according to Mr. Wm. Morin, the jaw bone of a mastodon was found a number of years ago. It was sent to St. Paul, but was lost in the capitol fire in 1881.

From Albert Lea to a distance of four miles northward, the valley of the Shell Rock river is occupied by modified drift, consisting of stratified fine gravel, sand and silt, or clayey sand. This deposit has an area from one and a half to two miles wide, about two-thirds of its width being on the west side of the stream. Originally this nearly flat plain was continous from the east to the west side of the valley, through which the Shell Rock river has since cut its channel about forty feet in depth. A portion fully a mile wide remaining on the west side of the river in sections 29, 31 and 32, Bancroft, is known as "Itasca prairie",* a little collection of houses in the southeast quarter of section 31 being called "Itasca". The level site of the town of Albert Lea, consisting of stratified fine gravel and sand, is part of the same formation, which here is underlain by a mud or fine sand of dark color, sometimes yielding branches or twigs of wood. Besides the extension of this deposit upon both sides of the Shell Rock river and Fountain lake to the west end of lake Albert Lea, it also reaches from Itasca prairie two miles southwestward, by White lake to Pickerel lake, its width for this distance being from one to two miles. It is here nearly level, with its surface about forty feet above Pickerel and White lakes; against which, as also at the end of lake Albert Lea, it is terminated by steeply sloping escarpments. The origin of these beds of stratified drift is believed to have been from the floods formed by glacial melting, chiefly during the final recession and departure of the ice-sheet. It has evidently been in some places excavated by streams since the ice age. Yet it can scarcely be supposed that the hollows of all these lakes have been formed by such erosion; in some instances they must apparently be attributed to the presence of masses of ice remaining where the lakes now are, causing their basins to be left empty when the adjacent plains of modified drift were deposited.

Another remarkable area of modified drift known by the name of "Bear lake prairie," is found in Mansfield and the west end of Nunda, reaching six miles from north to south and the same distance from east to west in this county, while its southern portion continues two miles or more into

*This was named Paradise prairie by Lieut. Albert Lea. See page 67.

Iowa. This is a flat plain, consisting, beneath its fertile soil, of stratified sand and gravel. It is bounded on the east and southeast by Bear lake and Lime creek. Rolling areas of till jut up, island-like, twenty to forty feet above this plain in the three miles next southwest from Bear lake. The highest part of this expanse is its northwest and west border, which rests, along most of its extent, on the flanks of morainic hills. From this side a scarcely perceptible slope descends eastward thirty or forty feet in a distance varying from three to six miles, and terminates by descending beneath the water-level of Bear lake, which this modified drift bounds with a very low and flat, marshy shore. It is evident that the waters from which this plain of sand and gravel was deposited flowed in the direction of its slope, from west to east; and it is demonstrable that they were poured down upon this area, loaded with detritus, from the melting surface of ice that covered the country adjacent westward.

Bear lake prairie is surrounded by knolly and hilly accumulations of till, with an abundance of boulders and stones enclosed and strewn upon its surface, belonging to the inner or western belt of the terminal moraine. At the east these scattered and irregularly grouped hills rise twenty-five to fifty feet above Bear lake and Lime creek. At the west, in sections 31 and 32, Mansfield, they rise fifty to one hundred feet above this plain of modified drift; and three to five miles farther northwest in Kiester, Faribault county, they attain a hight fully 150 feet above the upper west edge of this plain, or about 200 feet above Bear lake. From the Kiester hills a series of morainic accumulations extends twenty-five miles or more northwestward, crossing Faribault county. At two places on the west border of Bear lake prairie, head-streams of the East fork of the Blue Earth river have their sources and thence descend westward and northward. One of these is Brush creek, which begins upon an area of low, moderately undulating till in sections 29 and 30, Mansfield, and flows south of the Kiester hills. The other is Jones' or Dunnell's creek, which rises in springs in the northeast quarter of section 17, Mansfield, issuing at the base of a bluff or bank of gravel and sand about twenty-five feet in hight, from whose top the broad Bear lake prairie stretches eastward. For a considerable distance thence northward, in section 8, this stream flows in a ravine forty to sixty feet deep, enclosed by rough knolls of morainic till. Along its next mile,

in section 5, Mansfield, the morainic accumulations are less prominent and give place to smoother, undulating or moderately rolling till; except that here the stream is bordered by well-marked kames, or hillocks and ridges of water-deposited gravel and sand. One ridge, or kame, twenty to forty feet high, extends nearly a mile along the east side of the creek, separating it all this distance from a slough, to which two gaps supply outlets. Before these gaps were cut through, the slough was probably a lake. These kames are in large part gravel, very full of pebbles up to three or four inches in diameter, fully half of them being well water-worn. They also contain rarely boulders up to two or three feet in diameter. These rock-fragments, like those contained in the till of this region, are mostly granite, syenite, schists, and limestone. Though these kames are lower than the Bear lake prairie, they are believed to have been formed at a higher level, in the ice-walled channels of the glacial streams which carried forward their finer gravel, sand and silt to that plain. When the ice had wholly melted, these ridges of coarse gravel fell upon the till, which gradually descends northwestward from the moraine in a smoothly undulating surface, with no noteworthy accumulations of modified drift beyond these kames.

The plate (No. 14) which illustrates the geology of this county is designed only to show the features and distribution of the drift. In the areas represented as till-covered will be found numerous patches of modified drift which were too small to be noted. Of these, two areas of gravel and sand, which are more important than others, should be mentioned. One is along the Shell Rock river, particularly along the east side of the river, and the other extends northward from Geneva lake. Throughout the very rough portions of the morainic till there is also a frequent occurrence of large knolls and of flat tracts of modified drift, the morainic accumulation itself often consisting largely of this.

Wells. In the survey of the county considerable attention was paid to the phenomena of common wells with a view to learn the nature and thickness of the drift, and the following list is the result of notes made.

Good water is generally found throughout the county, in the drift, at depths less than eighty feet; but some deep wells that occur within the Cretaceous belt, in the western part of the county, are spoiled by the carburetted hydrogen. This must arise from carbonaceous shales in the Cretaceous, and indicates the extent of that formation.

The only well in the county that is known to have struck bed-rock is that of the Minneapolis and St. Louis railway at Albert Lea. It is near the station, on a flat which is about twenty feet below the main streets of Albert Lea and twenty feet above Albert Lea lake.

Deep well at Albert Lea.

1. Clay, said to be free from gravel..... 34 ft.
2. Quicksand..... 4 ft.
3. Clay..... 32 ft.
4. "Dark gray limestone," thought to be the same as that at Northwood..... 32 ft.
5. White sandrock, giving a little water, which rose to within twenty feet of

the surface..... 4 ft.

6. "Dark limestone," same as No. 4, with more water which rose to within six feet of the surface..... 41 ft.

Total depth..... 147 ft.

Notes of wells in Freeborn county.

Owner's name.	Location.	Depth in feet.	Kind of water.	Remarks.
W. P. Sargent	Sec. 29, Albert Lea	28	Good	½ bushel of coal at 27 feet.
Geo. Stevens	Freeborn	47	Carburetted	Pieces of coal in the blue clay; 26 feet of water.
T. A. Southwick	Freeborn	46	Soft	44 feet of water.
Ezra Stearns	½ mile west of Freeborn	30	Good	Found pieces of coal.
Ezra Stearns	½ mile west of Freeborn	42	Good	Found pieces of coal.
James Hanson	1 mile N W of Freeborn.	50	Carburetted	Found pieces of coal.
F. D. Drake	Sec. 13, Freeborn	90	Carburetted	Water stands 5 feet from the top.
O. U. Wescott	Byron, Waseca county	94	Soft	
L. C. Taylor	6 miles N. W. of Freeborn	96	Good	Artesian; at first bringing stones and gravel.
Geo Snyder, Jr	2 miles N. W of Freeborn	61	Carburetted	
A. M. Trigg	Alden	37	Carburetted	Found pieces of coal in clay.
H. M. Foot	Alden	50	Good	Found pieces of coal in clay.
John Melender	Alden	50	Good	Found pieces of coal in clay.
L. C. Taylor	6 miles N W. of Freeborn	96	Carburetted	Artesian
Wm. Comstock	3 miles N. E. of Alden	48	Carburetted	Nearly artesian.
Charles Ayers	N. W. corner of Freeborn	125		Bore for coal.
John Ayers	Trenton	142		Bore for coal; lost tools.
T. A. Southwick	Freeborn	35	Carburetted	Blue c ay; water in sand and gravel.
J. F. Jones	Geneva	10	Good	Water in quicksand.
Nelson Kingsley	Geneva	12	Soft	Water in quicksand.
John Farrell	Geneva	12	Soft	Water in quicksand.
A. Chamberlain	Geneva	12	Soft	Water in quicksand.
D G. Parker	Albert Lea	72	Good	Struck gravel below the blue clay.
Dr. C. W. Ballard	Albert Lea	38	Good	In gravel.
James Barker	Albert Lea	52	Good	Small bed of gravel in blue clay.
C. W. Levins	Albert Lea	25	Good	In gravel.
H Rowe l	Albert Lea	72	Good	In gravel below the blue clay.
W. W. Cargill	Albert Lea	85	Not good	Struck black clay, no sticks nor grit.
Charles Ostrom	Albert Lea	30	Good	In very fine blue sandy clay.
Lewis Gaul	Albert Lea	28	Good	"Yellow clay" all the way.
H. Rowell	Albert Lea	72	Good	Yellow and blue clay; then gravel.
Col. S. A. Hatch	Sec. 4, Albert Lea	42	Good	Gravel and sand; water in quicksand.
Ole Knutson	Albert Lea	34	Good	Gravel and sand; water in quicksand.
W. W. Cargill	Sec 28, Albert Lea	28	Good	Water in gravel.
Geo. Topon	Sec. 29, Albert Lea	65	No water	Gravelly clay; fine sandy clay; on rock.
And. Palmer	Sec. 29, Albert Lea	28	Good	Water in green sand.
Dr A. C. Wedge	Sec 8, Albert Lea	28	Good	Water in green sand.
W. C. Lincoln	Albert Lea	32	Good	Gravel and sand, then quicksand.
Frank Hall	Albert Lea	65	Good	Gravel and sand, then quicksand.
Town well	Alden	44	Good	In gravel.
A. W. Johnson	Albert Lea	80	Not good	Drift clay; water in gravel.
Rev. G W. Prescott.		80	Not good	"Tastes like kerosene."
Town well	Twin Lakes	75	Not good	Clay only.
	Alden	40	Not good	
A. Palmer, Jr	Sec 29, Albert Lea	30	Not good	Lump of coal at 27 feet.
Wm. Bell	Sec. 21, Newry	70	Good	Mainly in hard stony clay.
Jos. H. Butler	Sec. 28, Newry	75	Good	Mainly hard stony clay; water from gravel at 67ft.
James Bush	Sec 27, Moscow	32	Good	Water in sand and gravel below the blue clay.
Wm. Pace	S. E. ¼ sec. 34, Moscow	50	Good	Contains much wood; water seeps from blue clay.
S. G. Wat rs	Sec. 35, Hayward	40	Good	Inexhaustible water from quicksand.
G. D. Barron	S. E. ¼ sec 2, Shell Rock	38	Good	Water in sand at the bottom
Ingebret Erickson	N. E ¼ sec. 21, Bath	30	Good	Water from a thin bed of sand 10 ft. below suface.
Christ. Lyngby	Sec. 25, Bath	18		Water seeps from the yellow till
Mark A. Freeman	Sec. 14, Freeman	45	Good	Water from sand at the bottom, rising 20 feet.
John E. Hatle	N. W. ¼ sec 1, Hartland	16	Good	Water at 14 ft. in sand and gravel below yellow and blue till.
Ole Peterson	S. W. ¼ sec. 15, Manchester	75	Poor	Muck at 70 ft injures the water.
Rolf Thykeson	N. E. ¼ sec. 16, Manchester	125	Poor	Water rises from 100 ft ; stands 20 ft. below surface.
A. D. Le Fave	Sec. 2, Freeborn	70	No water	Passed through till, with some layers of sand.
Jason Goward	Freeborn village	95	Good	Water in gravel at 38 ft.
Asa Walker	Sec. 24, Carlston	100	No water	In till all the way.
James Fisk	Sec. 7, Alden	20	Good	Water from sand at the bottom.
J. A Burdick	S W. ¼ sec 24, Alden	15	Good	Water in sand at 12 ft.
Ole J Ophdal	Sec. 11, Mansfield	10	Good	All fine gravel and sand.
Knut Oleson Saland	Sec. 14, Mansfield	20	Good	All fine gravel and sand.
John Cross	N. W. ¼ sec. 20, Mansfield	30	Good	Gravel and sand, 18 ft ; till, 10 ft.
Edward Emerson	Sec. 22, Mansfield	44	Good	Water rises 25 ft from sand at the bottom.
A. H Stewart	S. E. ¼ sec 18, Mansfield	50	Good	Mostly gravel and sand, underlain by till.
Several other wells	Sec. 27, Mansfield	15 to 20	Good	Only sand and gravel
John Niebuhr	N. W. ¼ sec. 17. Mansfield	96		Water seeps from till at 16 ft ; only till.
Wm. Emerson	N. W. ¼ sec. 18, Mansfield	56	Scanty	Bored in clay
Wm Emerson	" (on lower land)	18		Water from gravel and sand at the bottom.
Several wells at	Norman station, Iowa	15 to 30	Good	Yellow and blue till.
Several wells at	Northwood, Iowa	12 to 16	Good	In gravel and sand, underlain by fossiliferous clay.

In some wells at Albert Lea a muck is found, and such wells are unfit for use. This muck is reported to contain sticks, and is about thirty-eight or forty feet below the surface. It may indicate a former bed of the river, or an interglacial marsh.* It is by some called *slush*, and

*The Great Ice Age. James Geikie.

seems not to uniformly hold sticks and leaves, but to be rather a fine sand of a dark color. The well-diggers call it quicksand. Dr. Wedge, of Albert Lea, thinks the site of the city was once covered by a lake, and that this *slush* was its sediment; and that the overlying gravel, which is about thirty-eight feet thick, has since been thrown onto it by a later force, perhaps by currents. There is no doubt that the overlying gravel was thus deposited, those currents being derived from the ice of a retiring glacier.

Wells at Geneva are generally not over twenty feet in depth. They also pass through a gravel that overlies a quicksand. This village is situated with reference to Geneva lake as Albert Lea is with reference to Albert Lea lake, both being at the northern extremities of those lakes. The phenomena of wells at the two places are noticeably similar and in the same way different from the usual phenomena of wells throughout the county.

At Albert Lea.

Gravel, about thirty feet.
Quicksand, with water, sometimes black and mucky.

At Geneva.

Gravel, twelve to fifteen feet.
Quicksand with water.

It would seem that the history of the drift at Albert Lea was repeated at Geneva. These villages being both situated at the northern end of lake basins, are probably located where preglacial lakes existed. On all sides, both about Albert Lea and Geneva, the usual drift clay, hard and blue, is met in wells, and has a thickness of about one hundred feet.

Vegetation in the drift deposits of Freeborn county. On sec, 34, Moscow, sticks, which were apparently of tamarack, were found "in gravel and clay," from thirty-five to fifty feet beneath the surface. They were from three to eight inches in diameter, and were associated with remains of crawfish and gasteropod shells. Several other wells in this vicinity have also contained wood. On sec. 22, Moscow, Mr. D. M. Farr found a log of tamarack (?) a foot in diameter, at twenty feet below the surface, which was said to have had the appearance of having been *chopped off* at the ends [probably gnawed by beavers]. It was accompanied by peat-moss and sticks a few inches in diameter.

In Shell Rock, S. E. ¼ sec. 2, Mr. G. D. Barron's well contained a small stick of wood eighteen inches long at about thirty-five feet from the surface, and a single fragment of lignite. On sec. 28 the well of Mr. W. H. H. Gordon contained wood at about twenty-five feet beneath the surface, with fragments of bark; also that of E. Barber, on sec. 29, at about the same depth.

In Manchester, sec. 15, Ole Peterson encountered a bed of muck in his well at seventy feet below the surface. It was a foot thick and injured the water.

As already stated, considerable soft muck is found in many wells at Albert Lea.

Boulders. A few years ago a boulder was found on the border of a marsh about twelve miles south of Albert Lea, in Shell Rock, near the state line, which was supposed to be of meteoric origin, and was carried to Albert Lea for preservation. It was owned by Mr. G. D. Parker. Of this stone no further note would be made, were it not that it has been regarded by many who have seen it as a true meteorite, and that such opinion has been published. When found it was at first nearly covered by earth. On excavation it proved to be dark colored. It was among other drift boulders scattered promiscuously about. It is roughly pitted and has fragments and pebbles of quartzyte standing out all over it. It is rudely pyramidal in form and contains something more than three cubic feet, weighing about five hundred pounds. A couple of thin quartz veins cross it from one end to the other, one of them, however, running off the surface before reaching the end, being nearly parallel with the sides of the mass. It also contains hornblende, and perhaps other minerals. The quartzyte is pinkish and compact, grayish. The mass contain, no iron that can be seen. The regular quartz seams are evidence of its having been embraced once in the rocky crust of the earth. The rough exterior is due to the weathering out of some of the softer materials. It seems to have come from the great Ogishke Muncie conglomerate; but it is a rare thing to see a fragment from that formation in the drift in the central and southern parts of the state.

A large boulder exactly like the above, but one-third larger, was found about the same time in Murray county, and was offered for sale in St. Paul, with the belief that it was a meteorite.

MATERIAL RESOURCES.

In addition to the soil Freeborn county has very little to depend on as a source of material prosperity. As already stated there is not a single exposure of the bed-rock in the county. All building stone and quicklime have to be imported. The former comes by the Southern Minnesota R. R. from Lanesboro in Fillmore county, or Stockton in Winona county, though it is very likely that the Shakopee stone from Mankato will also soon be introduced. The latter comes from Iowa, largely, (Mason City and Mitchell) and from the kilns at Mankato and Shakopee. Some building stone is also introduced into the eastern part of the county from the quarries at Austin.

Lime. At Twin Lakes three or four thousand bushels of quicklime have been burned by Mr. Carter from boulders picked up round the lake shores. This lime sold for seventy-five cents per bushel. It was very fine lime, and purely white. The construction of the railroad put a stop to his profits, as the Shakopee lime could then be introduced and sold cheaper. The boulders burned were almost entirely of the same kind as those that are so numerous in McLeod county. They are fine, close-grained, nearly white on old weathered surfaces, and of a dirty cream color on the fractured surfaces. They very rarely show a little granular or rougher texture, like a magnesian limestone, though this grain is intermixed with the closer grain. They hold but few fossils. There are a few impressions of shells, and by some effort a globular mass of coarse favositoid coral was obtained.

Besides the above, which are distinguished as "white limestone", there are also a few bluish-green limestone boulders. One of these, which now lies near Twin Lakes, is about seven feet long by five or six feet broad, its thickness being at least two and a half feet. It has been blasted into smaller pieces for making quicklime, but nearly all of it yet lies in its old bed, the fragments being too large to be moved. This stone is also very close-grained. It is heavier than the other and more evidently crystalline. It holds small particles of pyrites. It is not porous, nor apparently bedded. On its outer surface it looks like a weathered diorite, and it would be taken, at a glance, for a boulder of that kind. It is said to make very fine lime. Several hundred bushels of lime were formerly burned also at Geneva.

Brick. At Albert Lea the following persons have made brick:

George Broughton, Wm. Cook, G. C. Dillingham, and Rusfeldt and

Kleven. These all make what is known as "slop brick", i. e. they handle and dry them after mixing in water, without the use of sand. The latter method (with sand) is much quicker and pleasanter, but in the use of the brick there is not much choice between the methods. At Broughton's the brick are red. The clay used, which is about five feet below the surface, is fine and of a yellowish ashy color. It is underlain by gravel. The clay itself locally passes into a sand that looks like "the bluff". At other places it is a common, fine clay-loam, with a few gravel-stones. There is but little deleterious to the brick, in the clay, although some of the brick are, on fractured surfaces, somewhat spotted with poor mixing, and with masses of what appear like concretions. The clay itself is apparently massive, but it is really indistinctly bedded, rarely showing a horizontal or oblique, thin layer of yellow sand. Oak wood costs from five to six dollars per cord.

The yard of Mr. Cook also furnishes red brick. He uses the same stratum of fine clay overlain by the same yellowish sandy clay or loam. The clay here shows to better advantage and is plainly bedded. It contains sticks, the largest observed being a little over half an inch in diameter. These sticks are plainly endogenous in cellular structure, but have a bark. They are not oxidized so as to be brittle, but are flexible still, with small branches like rootlets hanging to them. It is uncertain whether they belong to the deposit, or are the roots of vegetation that grew on the surface since the drift. There are no boulders of any size in the drift just here; but a few granitoid gravel stones. The aspect generally indicates that this clay has a local character largely, but no outcropping beds can be found in the neighborhood. Mr. Cook has made in one year 250,000 brick. The yard has been running twelve years. Brick here sell for $1.30 per hundred, as they come from the kiln, or $10.25 per thousand. Hard brick from the arch sell at $1.50 per hundred. The brick here seem to show a little more lime, but they are well made and well burned.

About a quarter of a mile south of Albert Lea, in the west edge of sec. 16 of that township, bricks have been made by Rusfeldt and Kleven since 1873. For several years previous to 1880, they made 500,000 to 700,000 yearly, selling at $7.00 per M. In the spring of 1880 they were putting in brick-making machinery, and expected to produce 1,500,000 bricks that year. The clay forms a ridge fifty or sixty rods long from north-

west to southeast and about twenty feet high; it is yellowish in its upper ten feet and gray below. This clay when excavated and mixed from the upper and lower portions of the bank, contains the right proportion of sand, and none is used except for making the bricks slip from the mould. No fossils, as shells or wood, have been found in this deposit.

Bricks were formerly made at Geneva, and at a point about two and a half miles east of that place. At Geneva the clay was taken from the bank of Allen creek, about eighteen inches below the surface. It was a drift clay, with small pebbles. That used two and a half miles east of Geneva was of the same kind. In both places sand had to be mixed with the clay. About Geneva sand is abundant, taken from the gravel and sand knolls, and from the banks of the creek.

Peat. In Freeborn county there is an abundance of peat. The most of the marshes, of which some are large, are peat-bearing. In this respect the county differs very remarkably from those in the western portion of the same tier of counties, which, being entirely destitute of native trees, are most in need of peat for domestic fuel.

The peat of the county is generally formed entirely of herbaceous plants, though the marshes are often in the midst of oak openings. The peat-moss constitutes by far the larger portion. There is no observed difference in the peat-producing qualities between the marshes of the prairie districts and those of the more rolling woodland tracts of the county.

At Freeborn peat has been taken out on John Scovill's land. Here it is eight feet thick, two rods from the edge, and it is probably much thicker toward the center of the marsh. That below the surface of the water now standing in the drain is too pulpy to shovel out; and after being dipped out and dried on boards, it is cut into blocks and hauled to town. That above the water is more fibrous, and can be taken out with a spade in convenient blocks. Yet the level of the water varies, and that datum is not constant. It appears as if there were here a stratum of more fibrous peat, about twenty inches thick, that separates from the lower, and floats above it at certain times. In the peat at this place a sound elk-horn was taken out, at the depth of six feet.

There is a large peat marsh in sec. 11, Hayward, which extends also on much of secs. 12, 13, and 14.

CHAPTER XI.

THE GEOLOGY OF STEELE COUNTY.

BY M. W. HARRINGTON.

Situation and area. Steele county* (plate 15) lies in the second tier of counties from the Iowa line. It lies next west of Dodge county, being the fourth in number west of the Mississippi river. It has the form of a rectangle, and is bounded on the south by Freeborn, on the west by Waseca, and on the north by Rice county. The area of Steele county, compiled from the plats of the United States surveyors, is 430.59 square miles, or 275,579.16 acres, of which 2,817.69 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county is well provided with lakes, as may be seen in the following notes. Marshes also are numerous. These are due to the nearly level character of the county, and to the very slight elevation of one part above another. The small amount of slope in the surface is further shown by the sluggishness of the currents in the various streams. The course of the Straight river shows that some increase in hight occurs as we travel southward. But, although the county is very nearly level and has little change of elevation within itself, its elevation with reference to the rest of the state is considerable. This is shown by the fact that two streams originate here, viz: the Straight river in the southern part of the county, and a branch of the Zumbro.

Water-power in Steele county.

The small amount of fall of the streams limits the mill privileges in this county. The mills are found only on the Straight river, at Owatonna, and north.

The *City mills* at Owatonna, Drought and Whitson, owners. They have seven feet head of water, and three run of stone. It is a custom mill, but does a little export business.

*This county was examined in 1875, and was described in the annual report for that year. In the present report additional details are derived from Mr. Upham, respecting the drilling for an artesian well, the glacial drift, and sections of the drift shown by common wells.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

STEELE COUNTY

BY M. W. HARRINGTON.

WASECA COUNTY

BY WARREN UPHAM.

Explanation

Glacial Drift: Till, undulating or nearly flat; Till, rolling, or hilly; Terminal Moraines
Hudson River limestone and shale
Contour Lines are shown approximately for each 50 ft. above the sea

Note. The glacial drift is shown by wells to be underlain at several places by Cretaceous beds, which perhaps occupy a large part of these counties, but probably have no great thickness, and lie upon Lower Silurian formations.

Clinton mills are at Clinton Falls, Sherman and Winship, owners. They have ten feet head of water, and three run of stone. It is a custom and export mill.

Medford mills are at Medford, White, Beynon and company, owners. They have ten feet head of water and four run of stone. They do only an export business.

There is said to be an available water-power, unimproved, at Lindersmith's, between Owatonna and Clinton Falls.

Topography. This county is for the most part moderately undulating or nearly level, and is covered heavily by drift. As will be seen the rock appears at the surface only along the Straight river, near its exit from the county. Grassy swales are common and characteristic of the swamps, especially in Lemond township. Gravelly knolls are quite common in much of the county, especially in the southern part. They are short and steep in the southeast part of Somerset and the adjoining parts of Aurora, Summit and Blooming Prairie.

The following notes were taken from the field-notes and plats of the government survey in Steele county, access to which was obligingly given by the county register. The surveys were made in 1854.

Blooming Prairie was covered by thickets and low scrub for the most part. Marshes were numerous and there were two small lakes in the northern part of the township.

Aurora. This township much resembles the last; thickets and scrub over the most of it and numerous marshes, some of them quite large.

Havana. This township contains the major part of Rice lake. It is for the most part brushy or wooded, but the southwest part is prairie. Marshes are numerous but not large.

Merton. This township was found to be wooded on the south side and in the northwest corner. The remainder was prairie. A large marsh was located in sections 23 and 24, and many smaller ones were scattered over the country.

Summit was wooded in the eastern half, prairie in the western. A large branching marsh is located along the streams, and there are a few isolated marshes.

Somerset had several sections of prairie in the northeast corner, and the portion of the township lying west of the Straight river was prairie; otherwise it was wooded. The marshes platted are few and not large.

Owatonna. A band of woods, two or three miles wide, crosses the township, accompanying the Straight river and lying on its eastern bank. The remainder is prairie. The banks of the stream are bluffy. The site of the city of Owatonna was already in part claimed when the survey was made (1854).

Clinton Falls was mostly wooded, though a wedge of prairie lay between the Straight river and Crane creek. There was also a little prairie on the eastern border. There was a long marsh platted in sections 26 and 27.

Medford. This township is prairie, except for a wooded strip two to four miles wide, east of the river. The banks of the stream are rather bluffy.

Berlin was wooded through the center of the township; the remainder was for the most part prairie. The plats indicate marshes along the streams, and some other scattered marshy spots. Near the center lie Lonigan's and Beaver lakes, and in the southwestern part a pond. Beaver lake is said to be deep and clear, and to contain only soft water. This item, and much other valuable information concerning this county, the writer owes to Rev. G. C. Tanner, superintendent of schools for the county.

Lemond. The northwest part was woody and marshy, and there are besides two or three isolated groves of small extent. An extensive marsh crosses the north end of the township.

Meriden. This township was nearly all prairie, a little wood being found north of Crane

creek and also a small amount in the southern part. The land along the creek was marshy. On the northern boundary a small lake was found.

Deerfield. A lake enters from the south. Another of about 220 acres is platted just northeast of this, and near it is a pond of about half the size. All the township was wooded except the northwest corner, which was prairie. Extensive marshes were platted in the southern and western part.

On comparing the magnetic variations given on these plats, as observed during the survey in 1854, it is found that the extremes are 7° 37′ in Morton, and 11° 40′ in Deerfield, eastward from the true north.

Elevations on the Winona & St. Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Claremont (Dodge county)	76.36	1280
Havana	83.90	1246
Owatonna	88.17	1144
Meriden	96.35	1149
Waseca (Waseca county)	102.63	1153

Elevations on the Iowa & Minnesota division of the Chicago, Milwaukee & St. Paul railway.
From profiles in the office of George H. White, engineer, Minneapolis.

	Miles from St Paul.	Feet above the sea.
Straight river, water. 1069; grade	60.2	1090
Medford,	60.4	1098
Clinton Falls,	62.5	1107
Maple creek, water, 1113; grade,	65.9	1128
Owatonna,	66.6	1144
Summit, grade,	70.3	1245
Somerset,	71.7	1222
Aurora,	75.2	1253
Turtle creek, water, 1238; grade,	75.7	1246
Road crossing in section 34, Aurora,	78.5	1301
Summit, grade,	82.1	1313
Blooming Prairie,	84.6	1286

The hills of the terminal moraine in Blooming Prairie, Summit, Aurora and Somerset, are 1300 to 1350 feet above the sea, and are the highest land of this county. Its lowest land is where its northern boundary is crossed by Straight river, approximately 1060 feet above the sea. The extremes of elevation thus differ about three hundred feet.

Mean elevation of the county. Estimates of the average hight of the townships of this county are as follows: Blooming Prairie, 1300 feet above the sea; Aurora, 1280; Havana, 1240; Merton, 1240; Summit, 1250; Somerset, 1230; Owatonna, 1200; Clinton Falls, 1190; Medford, 1175; Berlin, 1250; Lemond, 1220; Meriden, 1175; Deerfield, 1160. The mean elevation of Steele county above the sea, derived from these figures, is approximately 1225 feet.

Soil and timber. This county has a fertile soil, and is wholly adapted for cultivation excepting a few unusually knolly tracts of small extent, and frequent sloughs which are valuable for their crop of marsh hay. Nearly all of the county is prairie, diversified here and there by tracts thinly wooded with bur oak. The only heavy timber of considerable area is found in a belt at the east side of Straight river, in Owatonna, Clinton Falls and Medford. The time spent in this county was not long enough to make out a complete list of its trees and shrubs. The following were noted.

Trees and shrubs of Steele county.

Tilia Americana, *L.* Basswood.
Rhus glabra, *L.* Smooth sumac.
Vitis Wild grape.
Ampelopsis quinquefolia, *Michx.* Virginia creeper.
Ceanothus Americana, *L.* New Jersey tea.
Acer saccharinum, *Wang.* Sugar maple.
Acer dasycarpum, *Ehr.* Silver maple.
Acer rubrum, *L.* Red or swamp maple.
Negundo aceroides, *Mœnch.* Box-elder.
Amorpha fruticosa, *L.* False indigo.
Prunus Americana, *Marshall.* Wild yellow or red plum.
Prunus. Cherry.
Rubus strigosus, *Michx.* Red raspberry.
Rubus villosus, *Ait.* Blackberry.
Pirus coronaria, *L.* American crab-apple.
Cornus paniculata, *L'Her.* Dogwood.
Symphoricarpus occidentalis, *R. Br.* Wolfberry.
Fraxinus. Ash.
Ulmus fulva, *Mich.* Slippery elm.
Ulmus Americana, *L.* White elm.
Juglans cinerea, *L.* Butternut.
Juglans nigra, *L.* Black walnut.
Carya. Hickory.
Quercus macrocarpa. *Michx.* Bur oak.
Quercus coccinea, *Wang.*, var. tinctoria, *Gray.* Black oak.
Corylus Americana, *Walt.* Hazelnut.
Ostrya Virginica, *Willd.*
Populus tremuloides, *Michx.* American aspen.
Populus grandidentata, *Michx.* Large-toothed aspen.
Populus monilifera, *Ait.* Cottonwood.

GEOLOGICAL STRUCTURE.

The glacial drift is so thick that it effectually conceals the underlying strata throughout this county, excepting slight exposures of the bed-rock in the valley of Straight river at and near Lindersmith's, two to three miles north of Owatonna. This rock has been referred, with some doubt, to the Hudson River epoch by Prof. Winchell. It certainly falls within the Trenton period, and may be lower than Hudson River.

The rock is an argillaceous and dolomitic limestone, and is first met at John Abbott's quarry, in section 33, Clinton Falls. It is in the bed and on the low banks of Straight river. The exposure at the time of examination extended only about four feet above the surface of the water. The rock is in horizontal layers, two to six inches thick. It is blue on fresh fracture, yellow when weathered, compact, sparry, and contains many minute fragments of blue shale. The loamy clay overlying was evidently not deposited by glacier ice, the rock *in situ* being rotted with age, like much of the rock in northeastern Iowa.

Just below, on section 28, is Lindersmith's quarry. The rock is in thicker layers than in Abbott's quarry. The following section was seen in one place, beginning above:

Loam	2 feet.
Black clay and limestone, in thin layers	2 feet.
Compact, blue limestone, in thin layers, to water's surface	4 feet.

The rock is like that in Abbott's quarry. Near by was another section as follows:

Black and red loam..... 2½ feet.
Hard, yellow clay..... 2 feet.
Blue stone, in layers two to five inches thick, extending to surface of water.... 7 feet.

Below this there is no more rock until the county line is passed. No fossils were found in the rock. This stone is used for flagging and other purposes at Owatonna, and is considered a good stone.*

Some evidence of the existence of Cretaceous beds was found. On the southeast quarter of section 26, of Deerfield, on the farm of Aug. Hoffmann, coal has been found in sinking a well. Dr. G. A. Rossbach states that they went through twenty-five feet of blue-black clay, in the under part of which were fragments of coal. After that they passed through gravel in which also were coal fragments. At the depth of sixty-three or sixty-four feet rock was struck; the drill showed it to be black shale with pieces of coal imbedded in it. Although no specimens of the coal were seen by the writer, the description given would answer for Cretaceous lignite. The evidence from the geology of adjoining counties, as well as the nature of the rock itself, justifies us in calling the rock Cretaceous. Just west of Owatonna another farmer is said to have struck coal also, though the writer was unable to get any further information on the matter.

Drilling for an artesian well. By a subscription of the citizens of Owatonna, a well was drilled in 1878, near the center of that city, to a depth of 387 feet. No artesian flow was obtained. Its site, a few feet higher than the depot, is approximately 1150 feet above the sea, being twenty-three feet above the top of the dam in Straight river, and some fifty or sixty feet below the average hight of the surrounding region. Mr. John Shea and Mr. Samuel H. Baker have furnished notes of the succession of beds penetrated by this well, as follows:

Section drilled for an artesian well at Owatonna.

		Thickness in feet.	Depth to top of strata.	Hight of top of strata above the sea.
1.	Gravel and sand	20	0	1150
2.	Blue, stony clay	14	20	1130
3.	Gravel and boulders, with much water	5	34	1116
4.	White quartz sand	21	39	1111
5.	Soft limestone, decayed	2	60	1090
6.	Yellow clay, making the water very yellow	1	62	1088
7.	White sandstone, quite hard	35	63	1087
8.	Blue, compact limestone	20	98	1052
9.	Blue sandstone, "like grindstone grit"	10	118	1032
10.	Blue shale	10	128	1022
11.	Light gray shale	10	138	1012
12.	Shale, "full of specks of iron pyrites, very hard to drill"	3	148	1002
13.	Blue shale	20	151	999
14.	Light gray shale	5	171	979
15.	Blue clay	12	176	974
16.	"Yellow, pyritous, very hard rock, appearing to contain scales of mica"	2	188	962
17.	Blue clay and shale	50	190	960
18.	Lead-colored clay, making the water dark-bluish	3	240	910

*See also the chapter on the building stones of Minnesota, pp. 176 and 200–203.

Glacial drift.]

19.	Like No. 16	7	243	907
20.	Blue shale, arenaceous	3	250	900
21.	Blue shale	8	253	897
22.	A cherty layer	1	261	889
23.	Blue limestone	28	262	888
24.	White sandstone	80	290	860
25.	Similar to the last but very hard, thought to contain iron pyrites	8	370	780
26.	White sandstone	9	378	772
	Total		387	Bottom, 763

These notes are discussed as follows by Mr. Upham, in respect to the geological age of the several parts of the section.

The first thirty-nine feet are *drift.*

The next fifty-nine feet, to a total depth of ninety-eight feet, appear to be *Cretaceous* deposits. Formations of this age, including thick beds of sandstone, occur in Blue Earth county and farther west in this state, in northwestern Iowa, and in Dakota; but no massive sandstone, as found in this well from the depth of sixty-three to ninety-eight feet, is known in any of the older formations of this part of the continent till the horizon of the St. Peter sandstone is reached, which surely underlies these and the next lower strata of this section.

From 98 to 118 feet is undoubtedly the limestone before described, which outcrops beside the Straight river within a few miles northward. In this well its hight above the sea is approximately 1030 to 1050 feet, its top being thus fifty feet, very nearly, lower than the quarries three miles farther north, in Clinton Falls. This stratum thus dips to the south about sixteen feet per mile. If the same dip continues through the eight miles northward from the Clinton Falls quarries to the point near the center of Walcott township, in Rice county, where the Straight river cuts through the Trenton limestone into the St. Peter sandstone, it would carry the horizon of the limestone found at the depth 98 feet, or 1050 feet above the sea, in the Owatonna well, and at about 1100 feet in Clinton Falls, to a hight 175 to 200 feet above the top of the St. Peter sandstone, which is 1040 feet, very nearly, above the sea, in Walcott and at Faribault. This consideration, and the character of the beds penetrated in the next 144 feet at Owatonna, consisting mostly of shale and clay, lead to the conclusion that these strata from 118 to 262 feet in the Owatonna well, correspond to those which were penetrated, having a thickness of about 100 feet, above the Lower Trenton limestone in the well at the State reform school, near St. Paul, as described in the report of Ramsey county.

The blue limestone, twenty-eight feet thick, next in the descending order, between 262 and 290 feet in depth, is quite certainly the *Lower Trenton limestone;* being the same formation that occurs at Faribault, and at St. Paul, Fort Snelling and Minneapolis.

The remaining ninety-seven feet to the bottom of this section are the *St. Peter sandstone.*

Glacial drift. The drift in Steele county consists chiefly of till, or clay, sand, pebbles and boulders, mingled in an unstratified deposit, of which clay is the prevailing ingredient. It reaches from the surface to a depth that varies in this county from fifty feet to probably a hundred feet or more. The contour of this region is smoothly undulating and often nearly flat, excepting two belts of knolly and hilly till, from one to several miles in width, which extend from north to south, divided by a tract of gently undulating till, from six to fifteen miles wide. These are moraines heaped at the east border of the ice-sheet of the last glacial epoch, as terminal moraines are formed at the end of alpine glaciers. A considerable retreat

of the ice, probably followed by a re-advance, took place between the time of accumulation of the eastern or outer belt of hills and hillocks and that of the inner, western member of this twofold formation.

In this county the eastern morainic belt extends through Merton, Havana, Aurora and Blooming Prairie, its eastern range of townships. It occupies the greater part of Merton, at the northeast corner of this county; but its hillocks, mounds or swells are only from twenty to thirty and rarely forty feet high. Most of them consist of till, or drift clay, enclosing boulders; but here and there are mounds of irregularly stratified fine gravel and sand. The east third of Havana has a similar rolling surface, bordering the west part of Rice lake. Through Aurora this moraine is well exhibited in scattered mounds and hillocks, fifteen to forty feet high. On the road from Owatonna to Blooming Prairie and Austin, it is crossed in sections 9, 15 and 22, being here about three miles wide. At Aurora station and for one and a half miles south, this formation is finely seen at the east side of the railroad, by which it is crossed in section 28. The boundaries of the moraine are very definite in this township. Its narrowest place in the county is found in section 28, north of which it is indented on the northwest side by a tract of lowland and marsh, which lies next west of the railroad, reducing the width of the hilly tract to one mile. At the west and southwest this quickly widens again to two or three miles, covering sections 29, 30, 31, and 32, of Aurora, and sections 25 and 36 of Somerset, with a profusion of knolls and hills, twenty to fifty feet high, sprinkled with boulders, principally granite and gneiss, mostly less than two feet in diameter, with occasional blocks or slabs of limestone, sometimes six or eight feet long. These elevations are seldom prolonged more than a few hundred feet. The trend of their longer axes is more frequently from east to west than otherwise, but this is not very noticeable. From the southeast corner of Somerset the moraine turns southward, and extends in typical hills and short ridges through the west two ranges of sections in Blooming Prairie. Here the trend of its separate elevations is most frequently from north to south, being parallel, as before in its east and west trends, with the course of the whole series. In the west part of sections 8 and 17, Blooming Prairie, these rough hillocks are well exhibited, being twenty to fifty feet above the depressions, and seventy-five or one hundred feet above the neighboring creek.

The largest boulders seen in this county are one about twelve feet in diameter at the Rock school-house in the southwest corner of section 8, Merton, and a second of about the same size beside the road in the northeast part of Summit.

The western or inner moraine lies in eastern Waseca county and in the southwest edge of Steele county, and extends from north to south in Freeborn county by Albert Lea, having a width that varies from three to ten or twelve miles. In Steele county this morainic belt occupies the southwest part of Meriden and the western two-thirds of Lemond and Berlin townships, being made up of massive swells of smooth contour, twenty to forty feet above the frequent depressions, many of which contain sloughs. The east portion of this prominently rolling land is three or four miles west of Straight river.

Wells in Steele county.

The records of the materials met in digging wells, examples of which are here given, further illustrate the character of the drift deposits.

Blooming Prairie. At the village the wells are 8 to 14 feet deep, averaging 10 feet. They go through till to the top of a stratum of quicksand, which has a considerable extent. The well at the south elevator was dark soil, 3 feet; hard, yellow till, 7 feet; and quicksand, 3 feet, penetrated with difficulty because of the large supply of water, which rises two to five feet above the top of this bed; to coarse gravel at 13 feet. This well and the similar railroad well, 14 feet deep, some twenty-five rods farther north, are the deepest here, no others having a depth of more than twelve feet. In wet seasons the cellars of this village are filled with water.

C. B. Pettie; sec. 24: well, 16 feet; soil, 2 feet; till, 14; quicksand at bottom. Wells in the vicinity are 15 to 25 feet deep, mostly less than 20; they obtain a large supply of excellent water.

C. J. King; N. E. ¼ of sec. 8: well, 15 feet; soil, 2 feet; clayey sand, 12; quicksand, 1 foot and extending below; water abundant.

Peter Thimson; also, N. E. ¼, sec. 8: well, 26 feet; soil, 2; sand to water at the bottom, 24 feet.

S. Peterson; N. W. ¼, sec. 9: well, 40 feet; soil, 2; gravel and sand, 8; yellow and blue till, 30; water rose 30 feet from sand and gravel at the bottom.

The three wells last described, and the next following, situated near the margin of the eastern terminal moraine, just outside the area that was overspread by ice, are in the modified drift which was deposited by water flowing from the wasting surface of the ice-sheet. These beds of stratified sand and gravel often reach a half mile to one mile away from the moraine upon its east side, varying in depth from 10 to 25 feet or more, with a smooth contour inclined slightly eastward

Aurora. John Bixby; N. E. ¼ of sec. 33, about thirty rods southeast from the boundary of the moraine: well, 29 feet deep; soil, 3 feet: coarse gravel, 2 feet; sand, 20 feet; blue till, 4 feet, and continuing lower; water comes in sandy veins in the till, not rising. Another well close southeast, and a third, one mile east, are likewise in gravel and sand, which here extend fully a mile from the edge of the morainic belt.

Havana. Wells at Havana station are shallow. J. S. Austin here went to a depth of 17 feet; the order being soil, 2 feet; sand, 4 feet; yellow till, 8 feet; and sand, 3 feet, not penetrated.

George L. Chambers; S. W. ¼ of sec. 20: well, 42 feet; soil, 2 feet; yellow till, 8; blue till, 32, water rose from quicksand at the bottom to a permanent level five feet below the surface in three hours. A few wells near the foregoing, about half a mile south of Havana station, find water at a depth of 40 feet that is offensive to smell and taste; but, excepting these, the water of wells and springs through all this region is good.

At the south side of the southwest quarter of section 29 are two flowing wells, the only ones learned of in this vicinity. The westmost, in the corner of this section, dug 16 feet and bored 18 feet lower, to a total of 34 feet, owned by Frank Truhlar, has been flowing twelve years. The other, about a third of a mile farther east, on John Chambers' farm, rented to L. L. Inman, is thought to be of nearly the same depth.

Merton. James Gibson; sec. 8: well 47 feet; soil, 2; yellow till, 10; blue till, spaded, 35; water stands 27 feet deep, rising from the bottom.

Somerset. G. Storer; sec. 33: well, 21 feet; soil, 2; yellow till, 8; harder blue till, 10; sand, 1 foot and extending lower, from which water rose 11 feet.

Lemond. C. G. Hersey; N. E. ¼ of sec. 21: well, 51 feet; soil, 2 feet; very hard yellow till, 10 feet; sand, 4 inches, containing water; blue till, picked, about equal in hardness with the yellow till, 39 feet, containing no layers of gravel or sand and no water.

Owatonna. In wells about Owatonna, sticks or fragments of wood are occasionally found in the till 30 to 50 feet below the surface; and a layer of peat is reported to occur under a considerable depth of drift, about three miles south of the city.

Mineral springs. The Owatonna mineral springs should be mentioned. They are nine in number, and are located about one and a half miles northeast of the city. They lie along Maple creek at the base of a low clayey bluff. Of the five seen by the writer, four deposited iron. The water of the fifth had a decidedly bluish tint. Fountain spring comes through a pipe that was put down twenty-two feet; the water flows out freely, rising about five feet above the surface. The others are natural springs. They are all undoubtedly due to the clay-floor underlying the loose material of the drift. The taste of the water in the five visited by me was slightly mineral. The analysis of the water, published by the Owatonna Mineral Springs company is appended. To which of the springs this analysis belonged could not be ascertained.

In one gallon, or 231 cubic inches, there are:

Chloride of sodium	.1680 grains.
Sulphate of sodium	.2856 grains.
Bicarbonate of sodium	1.8592 grains.
Bicarbonate of calcium	13.1992 grains.
Bicarbonate of magnesium	5.2920 grains.
Bicarbonate of protoxide of iron	.6160 grains.
Alumina	.2800 grains.
Silica	1. 1200 grains.
Organic matter	a trace.
Total	22.8200 grains.

Pottery and brick. Cornell Brothers, at Owatonna, manufacture stone ware. The clay employed is a fine, rich, plastic, blue clay, obtained from Eldora, Hardin county, Iowa. This bed of clay is being exhausted, and its quality is deteriorating. This has determined the firm to try a gray clay found about one mile east of Owatonna. This is the same layer of clay which crops out at the mineral springs near the city. It has been found

to work well. Excellent fire-brick are also made from this clay. This firm manufactures about 1,000 gallons a week in jars, jugs, &c.

Dr. E. N. Morehouse makes common brick from a bluish, yellow washed clay, near Owatonna. He puts in the clay about one-third sand. He makes 225,000 bricks a year, using fifty cords of wood for every 100,000 of bricks. The bricks are, like all of those made from the washed clay, not first-class. Dr. Morehouse has experimented on making unglazed red ware from his clay, with fair results.

Odell and Cornell also make bricks near Owatonna. Bricks are also made on the farm of Mr. Skinner, near Blooming Prairie.

Mounds. A series of large mounds, which have much the appearance of being artificial, are situated on the east side of the slough at Aurora station; and several others lie near the railroad a few miles farther south.

CHAPTER XII.

THE GEOLOGY OF WASECA COUNTY.

BY WARREN UPHAM.

Situation and area. Waseca county (plate 15, page 395) lies in the south part of Minnesota, in the second tier of counties north of Iowa. Its largest town and county seat is Waseca, in Woodville township, about 65 miles distant, in a direction a little west of south, from Saint Paul and Minneapolis, 93 miles west of Winona, and 40 miles north of the Iowa line. This county is a rectangle, twenty-four miles long from north to south and eighteen miles wide from east to west, including twelve townships of the governmental surveys, each of which, six miles square, is an organized civil township. The area of Waseca county is 437.01 square miles, or 279,685.91 acres, of which 11,524.16 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Le Sueur river has its farthest sources in the southeast part of Waseca county and in the adjoining edges of Steele and Freeborn counties. This stream and its tributaries drain all of Waseca county excepting its northeast corner.

The main Le Sueur river runs from the southeast corner of this county northerly six miles through the east part of New Richland; then westerly through southern Otisco, into the southeast part of Wilton; then again northerly six miles to Carr's ford, in the southeast part of Saint Mary township; and thence westerly eleven miles through the north part of Saint Mary and Alton. On the right this stream receives small tributaries in sections 7 and 6, Otisco, the latter being named McDougal creek, and in sec. 34, Saint Mary. Its only considerable tributary on the left in this county is Boot creek, which comes from the south, approximately coinciding in its course with the boundary line between New Richland and Byron.

About a quarter of Waseca county, at the southwest, sends its surplus waters to the Le Sueur by the Big Cobb river, which flows through the south part of Vivian; while a branch of it, the Little Cobb river, and Bull run, tributary to the last and the outlet of Silver lake in Wilton, flow westerly across Freedom township, into Blue Earth county.

At the northwest, nearly all of Janesville, western Iosco, and the north part of Alton are drained by the way of lake Elysian and its outlet, which also passes into Blue Earth county and

is there tributary to the Le Sueur river. Iosco creek, the largest stream that enters lake Elysian, receives a branch from the southwest named Silver creek.

The basin of the Cannon river extends into the northeast part of Waseca county, including northeastern Iosco, Blooming Grove, and the north part of Woodville, in all about sixty square miles. A considerable creek runs from Iosco northward to Waterville, and there empties into the west part of lake Sakata, through which the Cannon river flows; and Crane creek, tributary to the Straight river in Steele county, and by that to the Cannon river, has its source in Rice and Watkins lakes at the north line of Woodville.

Lakes. Lake Elysian, the largest body of water in this county, is five miles long and from a third of a mile to one mile in width. It has a north-northeast trend, and lies mainly in Janesville, but its north end is crossed by the county line. Rice lake, one and a third miles long from west to east, in sections 5, 6, 7 and 8, and Willis lake, in the southwest quarter of section 9, Janesville, lie west of lake Elysian; and lake Lily, and Reed's and Toner's lakes, each about a mile long, with east-southeast trends, extend in a series southeastward from Okaman at the head of lake Elysian, lying, except the northwest end of lake Lily, within the northwest quarter of Iosco. Helena lake, about three-quarters of a mile long from west to east, is crossed by the line between section 31, Iosco, and section 36, Janesville. Four small lakes, a quarter to a half mile in length, lie in Blooming Grove township. Rice lake, covering about a square mile, is crossed by the south line of Blooming Grove, its greater part being in Woodville; and close on its east side is Watkins lake, half as large, lying mainly in section 3, Woodville. Four other lakes lie in this township, within view from the Winona & St. Peter railroad. The first of these seen in proceeding westward is Goose lake, about one and a half miles long from northeast to southwest, lying at the north side of the railroad, three miles east of Waseca. Within a mile east of Waseca, this road goes between Clear lake, one and a half miles long from north to south and half as wide, lying on the north, and Gaiter lake, about a mile long from north to south and a quarter of a mile wide, on the south. Close west of Waseca, Loon lake, lying north of the railroad, has about the same extent as Gaiter lake, but with trend from east to west. Other noteworthy lakes in this county include lake Canfield, in the northeast part of Otisco; Thompson lake, two-thirds of a mile long from east to west, in the north half of section 13, New Richland; Silver lake, nearly two miles long from northeast to southwest and a half mile wide, in the west part of Wilton; Wheeler lake, a half mile long, in section 5, Vivian; another, of similar size with the last, in the north part of see. 26, Freedom; Mud lake, also of small size, being about two-thirds of a mile long with trend from east to west, in section 11, Alton; and Buffalo lake, the largest, excepting lake Elysian, in this county, situated near the center of Alton, two miles long from northwest to southeast, having an area of about a thousand acres.

Topography. The minor surface features of this county have been determined by the conditions attending the accumulation of the glacial drift or till. Its contour records the direction in which the ice-sheets moved, and their boundaries, the form given to the surface of this deposit being apparently quite independent of the small inequalities of the underlying rocks. Upon these the drift rests as a continuous mantle, filling up their depressions and making a more even expanse than those rocks probably exhibited before the glacial period, or would now show, were the covering of drift removed. The great slopes of the country, however, which shape its basins of drainage and determine the general course of its rivers, are due to the gradual changes in altitude of the older strata on which the drift lies. Thus the southeast part of Waseca county is more than a hun-

dred feet higher than its west side because the bed-rocks underlying the till rise highest in that part of the county.

For a correct understanding of the origin of the topographic features of the drift-sheet, we need to review briefly the history of the glacial period. It is proved that this included several epochs of severe cold in which nearly all of the state was buried beneath a thick sheet of ice like that now spread upon the Antarctic continent and the interior of Greenland. Between these cold epochs were others when a milder climate reigned, and these accumulations of ice were partially or wholly melted away, giving place to animal and vegetable life upon the land, remains of which are preserved in fossiliferous beds enclosed between deposits of till. At least two glacial epochs have left very clear records of the extent reached by the ice-sheets. The earlier carried its drift as far south as Saint Louis, and nearly to the Ohio river on the east, even crossing this river at Cincinnati, as shown by Prof. Wright, and beyond the Missouri river on the west; but left a driftless area, which was surrounded by this ice-sheet, in southwestern Wisconsin and portions of the adjoining states, reaching from southeastern Minnesota eastward to the Wisconsin river and southward to the northwestern corner of Illinois. The later ice-sheet, which moulded the surface of this county, was of less extent. Its southern portion was divided into great lobes, somewhat as the earlier continental glacier had been parted at the driftless area, though again confluent farther south. The boundaries of this lobed ice-sheet of the last glacial epoch are marked by very distinct series of terminal moraines, or belts of hilly and knolly drift, which appear to have been deposited at the margin of the ice, corresponding to the drift heaped at the termination of alpine glaciers. These moraines have been traced, in a very irregular, looped course, through Wisconsin, Minnesota, Iowa, and Dakota. The glacial lobe whose eastern portion covered Waseca county stretched southeasterly from western Minnesota to central Iowa. Its eastern border, marked by moraine deposits, reaches from the Leaf hills in southern Otter Tail county southeasterly by Glenwood in Pope county to lake Minnetonka, and thence southerly, passing through Waseca, Steele and Freeborn counties, to the vicinity of Des Moines; whence its western border, shown by the continuation of this moraine, joined with the preceding by a U-shaped curve, extends northwesterly by Spirit lake and through southwestern Minnesota, to the Head of the Coteau des Prairies, in Dakota, twenty-five miles west of lake Traverse. The large area within this looped boundary was covered by ice so deeply that the pressure of its weight caused it to flow slowly outward from the center, where its thickness was greatest, toward each side, accumulating these hillocks of drift at its margin. At the same time a glacial current from the thicker northern ice was pushed southeasterly along the axis of this vast lobe and was deflected into its outward currents, as the trunk of a tree sends out divergent branches.

The moraines formed at the borders of this ice-lobe, both on its east and west sides, are mainly double, showing two well-marked belts of roughly knolly and rolling drift, each a few miles in width, divided by a tract of smoother surface, from two or three to twenty-five miles wide. As the course of this formation makes a loop like the letter U, having been accumulated by ice-fields covering the district enclosed, the outer moraine on each side is known to have been first made; and then, after a retreat of the ice-sheet, probably followed by a re-advance, the inner moraine was formed; for the latter would have had its very uneven surface planed off and mostly leveled, if it had been covered by a moving ice-sheet, forming terminal deposits beyond it.

South from Faribault to the Iowa line the moraine accumulated on the east side of this ice-lobe is twofold, and consists of approximately parallel belts of knolly and hilly till, from one to several miles in width, extending from north to south, between which intervenes a tract of gently undulating till, from six to fifteen miles wide. Of these the eastern or outer morainic belt extends through the eastern range of townships in Steele county. The western or inner moraine lies in eastern Waseca county and the southwest edge of Steele county, having a width that varies from three

to ten miles. Its hills are almost universally till or unmodified glacial drift, rising in smooth but variable slopes, and exhibiting no parallelism or system in their trends. From Okaman, at the north line of Waseca county, and from Waterville, in Le Sueur county, southeastward through the northeast part of Iosco and the west half of Blooming Grove, to the southwest corner of this township, two miles north of Waseca, these elevations are 30 to 50 feet high. Through Woodville, within two to four miles east and southeast from Waseca, inconspicuous scattered drift hills and mounds, constituting a generally rolling surface, represent the morainic series. In Otisco, the next township south, it rises to its usual prominence in section 5, one and a half miles east of Wilton, where we find numerous steep ridges and round or irregular hills, more strown with boulders than the other portions of this township, which are moderately rolling and occasionally hilly. The east two ranges of sections in New Richland are included in this belt, being mainly covered by morainic mounds, swells and hills, 30 to 50 feet above the intervening hollows.

In the northeast corner of Waseca county, the east half of Blooming Grove and the northeast edge of Woodville are part of the gently undulating area between these morainic belts. The contour is approximately level, as seen in any extensive view, but it includes occasional broad hollows which are depressed 20 to 25 feet.

The northwest part of this county, west of its moraine, is also moderately undulating or rolling, in prolonged, smooth slopes, the highest swells being 10 to 30 or 40 feet above the neighboring sloughs and lakes. This description applies to Janesville, southwestern Iosco, Alton, and Saint Mary; and in the southeast part of this county the western two-thirds of New Richland have a similar surface.

About a third of Waseca county, including its southwestern townships of Freedom, Wilton, Vivian and Byron, is a very flat expanse of till, in some parts imperfectly stratified. The difference in elevation between the highest and lowest portions of the surface, connected by slopes from a quarter of a mile to one mile in length, is only five to ten feet. This is the eastern margin of the vast intra-morainic area of slightly or moderately undulating till which extends from here northwest to Big Stone and Traverse lakes and the Red river valley, its width being from the moraine of the Leaf hills and lake Minnetonka on the northeast to that of the Coteau des Prairies in southwestern Minnesota. The very smooth and often almost perfectly flat surface of these townships, and of a large part of Blue Earth and Faribault counties appears to have been due to the leveling ac-

tion of a lake that covered this district during the departure of the last ice-sheet. In its recession northward the ice was a barrier which prevented the water of its melting from flowing away in its present course, following the northern slope of the land; so that a lake, similar in its origin to lake Agassiz in the Red river valley, extended over the greater part of the basin of the Blue Earth and Le Sueur rivers, its area being increased as fast as the border of this ice-lobe retreated to the north, till it was so far melted as to permit this glacial lake to be drained northward by the Minnesota river. Its outlet, while it remained a lake, is found in Iowa, and was tributary to the East fork of the Des Moines river, as described in the report of Faribault county.

Channels, ten to twenty-five feet in depth and five to ten rods or more in width, which may have been eroded by rills and streams under nearly the present conditions of climate, but have no water now running in them through the greater part of the year, cross the flat area of southwestern Waseca county in irregular courses. This area also contains here and there broad, bowl-like depressions of similar or somewhat greater depth, often with no outlet or depression continuing away on any side, and occupied by sloughs and lakes. These hollows sometimes have steep sides, which have been eroded and undermined by waves; but generally they are surrounded by slopes of 10° to 15°, about a third as steep as are produced by the falling down of a bluff of drift that has been undermined by water. In origin they seem to be like the basins of the ordinary small lakes that are scattered irregularly over the surface of the moderately undulating drift-sheet of this state. Variations in the direction or force of the glacial currents, and consequent irregularities in the amount of drift deposited or eroded by the ice-sheet, have commonly moulded this formation in swells and hollows, the latter being often without outlet. Here the surface has been smoothed by an extensive glacial lake, and the drift that would have formed swells has been swept into the adjoining hollows; but it appears that occasionally the supply of material thus carried into the depressions was insufficient to fill them, and their deep central portions remain empty, constituting very remarkable features in the topography because of the unusually flat tract in which they occur. These basins vary from 20 to 30 or 40 feet in depth, and in extent they are from thirty rods to one or two miles long, with perhaps half or two-thirds as great width, the largest area of this kind being that of Silver lake in Wilton. The shallowest hollows filled by sloughs are only two to five feet lower than the surrounding land, while the deepest are twenty feet below the general level.

Streams in this part of the county, as the Little Cobb river and Bull run, have cut valleys 20 to 30 feet deep. Boot creek, east of Byron, lies in a broad, shallow depression of slightly undulating till, two or three miles wide and 20 or 30 feet below the average surface on each side. The valley or channel eroded by the Le Sueur river in New Richland and southern Otisco is 20 to 30 feet deep; and in the remainder of its course through this county, passing by Wilton and Alma, its depth is about 40 feet.

Elevations on the Winona & Saint Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Meriden (Steele county),	96.35	1149
Waseca,	102.63	1153
Janesville,	112.91	1063
Eagle Lake (Blue Earth county),	122.56	1012

Elevations on the Minneapolis & Saint Louis railway.
From Robert Angst, assistant engineer, Minneapolis.

	Miles from Minneapolis.	Feet above the sea.
At the north line of Waseca county,	67.0	1049
Iosco,	69.7	1146
Summit, natural surface, 1168; grade,	70.3	1154
Loon lake, water,	75.7	1134
Crossing Winona & Saint Peter railroad,	76.0	1154
Waseca,	76.2	1151
Creek in sec. 8, Otisco, water, 1071; grade on bridge,	81.2	1077
Le Sueur river, water, 1103; grade on bridge,	84.8	1116
New Richland,	88.7	1178

The highest portion of this county is the east half of New Richland and the southeast quarter of Otisco, which are about 1200 feet above the sea. Its lowest land is where the Le Sueur river and other streams cross its west line, at hights between 1000 and 1050 feet above the sea, the elevation of the Le Sueur river at this line being approximately 1010.

Mean elevation of the county. Estimates of the average hight of the townships of Waseca county are as follows: Blooming Grove, 1150 feet above the sea; Woodville, 1150; Otisco, 1160; New Richland, 1190; Iosco, 1100; Saint Mary, 1120; Wilton, 1110; Byron, 1150; Janesville, 1060; Alton, 1060; Freedom, 1070; and Vivian, 1100. The mean elevation of the county, derived from these figures, is approximately 1120 feet.

Soil and timber. The black soil varies in thickness from one to three feet, being least on swells and on the hillocks of the moraine, and greatest in depressions. It is a very fertile gravelly clay, with occasional boulders, and differs from the subsoil, both of which are till, in having been enriched and colored by the decay of vegetation through many centuries. This glacial drift includes a considerable proportion of limestone, both as boulders and pebbles, and also in a finely pulverized condition, which contributes in an important degree to the productiveness of the soil, and at the same time makes the water of wells hard. Wheat, oats, corn, potatoes, flax, sorghum, and all the crops that belong in this latitude, are successfully cultivated.

Timber covers the greater part of Janesville, the west half of Alton, and northwestern Iosco, this being the southeast edge of the Big Woods. About half of Blooming Grove is also wooded, and numerous large groves occur in the townships of Saint Mary, Woodville and Otisco, and in the northeast part of New Richland. The Le Sueur river is bordered by timber,

which attains a width of one to one and a half miles at the east side of this stream in the southeast part of Wilton and the adjoining edge of Otisco. Southwest from the Le Sueur river, the flat expanse which reaches thence to the limits of the county is prairie, and its green mat of grass sometimes bears no tree nor bush within an area several miles in extent. The lakes, however, within this tract are usually bordered by wood, and belts of timber mark the course of its streams.

White and slippery elm, bass, sugar and red maple, box-elder, black and bur oak, butternut, white and black ash, ironwood, wild plum, Juneberry, American crab-apple, common poplar or aspen, cottonwood, and willows, are the principal species of trees in this county.

GEOLOGICAL STRUCTURE.

No outcrop of the strata underlying the drift occurs in Waseca county, but they have been reached by wells at three localities. One of these wells, reported by Prof. L. B. Sperry, "near Janesville, after passing through 200 feet of blue clay, reached a sandstone said to be identical with the St. Peter in appearance. An abundance of good water, which rose to within 30 feet of the surface, was found between the clay and the sandstone."

At the town of New Richland, a well at Dunwoody & Corson's mill reached a depth of 110 feet, finding the following section: soil, 2 feet; yellow till, with streaks of sand, yielding water, 30 feet; blue till, softer and sticky, 66 feet; sand, 2 feet; and hard, straw-colored sandstone, 10 feet. At this depth water was struck, and rose in two minutes to 30 feet below the surface. Another well at this mill, 149 feet deep, drilled by Mr. C. E. Whelpley, is reported by him to be drift, 107 feet; yellow calcareous sandrock, 40 feet; and similar rock of blue color, 2 feet. A very large supply of water was obtained, rising to the same hight as the last. The well at the depot, about forty rods north of the foregoing and on land of the same hight, is 129 feet deep, and found the soil 2 feet thick; yellow till, spaded, 10 feet; blue till, mostly very hard, picked, 115 feet; and yellowish sandstone, similar to that of Dunwoody & Corson's well, 2 feet and extending lower. Water, found in this sandstone, rose 80 feet. It is noteworthy that the top of the bed-rock in these wells, only an eighth of a mile apart, differs about 25 feet in hight, probably on account of erosion in a formation

horizontally stratified. About three miles northwest from New Richland, a well 110 feet deep on S. W. Franklin's dairy-farm, went 10 feet into this rock, after penetrating 100 feet of drift, obtaining water in the rock which rose to ten feet below the surface. At Owatonna on the northeast, and at Wells, in Faribault county, on the southwest, similar formations of sandstone, with associated layers of shale and limestone, encountered by deep wells, appear to be of Cretaceous age; and very probably these beds and the sandstone of New Richland belong to the same horizon. The evidence pointing to these conclusions is set forth in the report of Faribault county, to which the reader is referred.

Drift. Under the description of the surface features of this county, its glacial drift and terminal moraine have been already described in a general manner. The thickness of the drift varies from one hundred to two hundred feet over this county and a large adjoining region. This formation is principally the unstratified gravelly and stony clay called till, boulder-clay, or hardpan, with which are associated beds of modified drift, which were gathered from the melting ice, assorted and deposited by water. The following notes of wells exhibit in detail the character and order of the drift deposits.

Wells in Waseca county.

Blooming Grove. William Habine; sec. 3: a well 100 feet deep in till found no water; while another well only 16 feet deep, six rods farther east, on land of about the same hight, found plenty of water.

I. D. Beeman; sec. 10: well, 24 feet; soil, 2 feet; yellow till, 21 feet; blue till, soft and sticky, 1 foot and extending deeper; the water seeps.

P. Healy; sec. 15: well, 20; soil, 2; yellow till, 10 feet, containing veins of gravel, two to four inches thick; harder blue till, 8 feet; the only water obtained is from sandy and gravelly veins in the upper till.

Waseca, in Woodville. William Everett: well, 68 feet; soil, 3 feet; till, yellowish in its upper portion and bluish below, 47 feet; vein of sand, 6 inches; blue till, 15 feet; sand and gravel, 3 feet and reaching lower; from this bed, water rose to the vein of sand at 50 feet, there running off.

At McCutchins' elevator, on the Winona & St. Peter railroad, a well 140 feet deep is reported to have been all drift, but no particulars were learned. Water rises from the bottom to stand ten feet below the surface. No thick beds of sand are found here enclosed in the till, and no bed-rock is reached. Most of the wells of this town are only 15 to 20 feet in depth, and find water in the lower part of the yellow till.

Otisco. J. A. Canfield; sec. 3: well, 22 feet; soil, 2 feet; yellow till, 14 feet, shoveled, containing streaks of sand; blue till, harder and more gravelly, picked, 6 feet; water is found only in the yellow till.

Knut H. Esping; sec. 13: well, 24 feet; soil, 2; yellow till, shoveled, 12; sand, 3 feet; blue till, picked, much harder than the upper till, 7 feet; to sand at the bottom, from which water rose seven feet, flowing off in the upper sand.

New Richland. Wells in this town, penetrating to the bed-rock, are described on the preceding pages.

Iosco. N. N. Norcutt; S. E. ¼ of sec. 30: well, 30 feet; soil, 2 feet; yellow till, 18 feet; much harder blue till, 10 feet; the water seeps from the yellow till, and is excellent.

Saint Mary. E. Brossard; sec. 2: well, 16 feet; soil, 2; yellow till, 10; much harder blue till, 4; water seeps from the upper till.

Wilton. At the town, in sec. 1, a well for a steam saw-mill went 90 feet, its lower and greater part being in soft blue till, finding no water.

John McLin; sec. 20: well, 22 feet; soil, 2; yellow till, hard, but spaded, 18 feet; softer blue till, 2 feet and extending deeper; the water comes in seams of sand in the lower part of the yellow till.

Hans Krager; sec. 36: well, 30 feet; soil, 2; yellow till, shoveled, 6; blue till, harder, picked, 22 feet; no sand nor gravel was found in the blue till, and no water was obtained.

Byron. Garrett Hope; sec. 6: well, 38 feet deep, the only "fountain," or flowing well, in this township; soil, 2; yellow till, 10; blue till, 25; very hard, dark layer, 6 inches; gravel and sand, 1 foot, and extending lower, from which water rose instantly to the top, and has since flowed away from the mouth of this well during four years. This water threw up the auger and shafting, with which the well was being bored, weighing five hundred pounds or more, fourteen feet, and filled the boring with gravel to that hight. The site of this well is about fifteen feet below the general level of the country.

Janesville. The deepest wells learned of in this township are at the elevator beside the railroad near the depot, said to have been bored 150 feet, with loss of two sets of boring tools, but thought not to have reached the bed-rock; the well at the Taopi mills, 100 feet deep, in which the water rises to 60 feet below the surface; and the well at the railroad station, 76 feet in depth. The latter was dug twelve feet square for 56 feet, and then bored 20 feet more, finding a large supply of water, which, however, does not rise so as to fill the bottom of the portion dug. From all that could be gathered respecting these wells, they appear to have been till, with no notable layers of sand or gravel. The common wells of this town and its vicinity are 12 to 20, or sometimes 40 feet deep. Mostly they get water by its seeping from the yellow till. Wells that go lower sometimes find layers of dry quicksand in the blue till, ready to drink up the water derived from sandy streaks in the upper till.

Alton. E. F. Nettleton; S. W. ¼, sec. 32: well, 28 feet; soil, 2 feet; yellow till, 24; gravel, 1 foot; blue till, softer and more sticky than the upper till, 1 foot and extending lower; water rose five feet.

Alma. W. E. Lockwood: well, 46 feet; soil, 2½ feet; yellow till, 17 feet; harder blue till, 10 feet; sand, 6 inches; blue till, as before, 15 feet; gravel, 1 foot, from which water rose seventeen feet.

Alma City flour-mill: well, 63 feet, the deepest in this vicinity; soil, 3 feet; yellow till, 6 feet; harder blue till, 20 feet; gravel and sand, 5 feet; blue till, 25 feet; gravel and sand, 4 feet and reaching lower, from which the water rises thirty feet.

Freedom. Chris. Priem; sec. 23: well, 64 feet; soil, 3; yellow till, 14; soft blue till, 20; darker till, very hard, 13; soft blue till, 5 feet; dry sand and gravel, containing gas, which rose with such force as to throw up the gravel and sand three feet, and continued "blowing" three days; this stratified drift was penetrated to a thickness of 9 feet, and extended lower; water was found in the last four feet.

Henry Converse; S. W. ¼ of sec. 27: well, 107 feet, the deepest in this part of the county; soil, 3; yellow till, 16; soft, blue till, 88 feet, containing a layer of dry sand one foot thick at 70 feet below the surface; no water is found in this blue till; the well is used, but has only "surface water," which seeps from the upper till.

Vivian. Henry Laver; sec. 3: well, 95 feet; soil, 3; yellow till, 16; soft blue till, 30; dark till, very hard, 20; soft blue till, 25; black sand, 1 foot; water rose to five feet below the top in three hours.

John Bushou; sec. 12: well, 37 feet; soil, 3 feet; yellow till, 13; soft, blue till, 18; darker very hard till, 2 feet; gravel, 1 foot and extending lower, from which water rises and flows over the top of the well, making it a fountain.

Mr. Clarence W. Converse, well-maker, living on the S. W. ¼ of sec. 27, Freedom, thus sums

Material resources.]

up his experience in boring some two hundred wells in this and neighboring counties: The yellowish upper till is harder to bore than the blue till next below, which is moist and sticky, the auger going down five feet in the latter as easily as two feet in the former; but a third kind of till, called "hardpan," darker than the soft blue till, is generally as hard as the yellow till, and often, probably in half the instances of its occurrence, it is harder. The upper, yellow till is characterized by sandy streaks, and crevices which yield seep-water, found in half of all the wells. It is almost always directly underlain by the soft and moist blue till, which has no crevices with seeping water, but bears sand-veins from two or three inches to four feet thick, which contain water. The very hard, darker till is similar in yielding water with the last.

The maximum thickness of the yellow till found by Mr. Converse was 35 feet, in Spring Lake, Scott county. The greatest thickness of the soft blue till found is 88 feet, at his home in sec. 27, Freedom. The thickest bed of the very hard, darker till was 40 feet, occurring at French lake, in Rice county, six miles northwest from Faribault. An average of the thickness of this dark hardpan may be eight or ten feet; and about a quarter or a third of its beds are only from one to five feet thick. Fragments of lignite, up to four inches in diameter, are often met with in these drift deposits, most frequently in the dark hardpan. Pieces of wood, up to one foot long, are found rarely, but no shells nor other organic remains have been noticed.

MATERIAL RESOURCES.

The agricultural capabilities of Waseca county, its fertile soil, and its good supply of timber, have been spoken of on page 409.

No water-powers have been utilized in this county.

Drift boulders are the only stone found for the construction of foundations, walls of cellars and wells, culverts, etc. These boulders occur quite commonly upon the morainic belt, and are found sparingly in all parts of the county. They are mostly varieties of granite, syenite, and gneiss, with occasional blocks of limestone. In size they reach to five feet, and rarely to ten feet in diameter.

Lime has been burned from the boulders of magnesian limestone in the drift by E. R. Tuttle in Janesville, during the last twelve years, producing annually from 100 to 200 barrels, selling it at about $1.25 per barrel. The greater part of these boulders, estimated to be three-fourths or more, make white lime; while the remainder yield lime of yellowish or darkish gray color.

Brick have been made also by Mr. Tuttle about a third of a mile northwest from Janesville during the past twelve years, producing from 100,000 to 400,000 yearly, selling at about $7 per M. He uses stratified yellow and gray clay, which contains sandy layers so that it needs no intermixture of more sand. It is excavated to a depth of five feet. These bricks are red and of good quality.

In the northwest $\frac{1}{4}$ of sec. 2, Iosco, close to the north line of this county,

and one and a half miles south of Waterville, red brick have been made during several years by Mr. David Wood, producing 200,000 to 300,000 annually, of excellent quality, bringing $7 to $8 per M. The clay used is stratified. It contains no sand in its upper four or five feet; but its layers below are separated by little seams of sand, occasionally with a thin film of iron-rust. This clay-bed extends to a depth of at least 13 feet, and is sufficient to make many millions of brick.

A kiln of red bricks, inferior in quality because cracked after burning by particles of limestone contained in the clay or sand used, was burned by I. C. Trowbridge several years ago in Woodville beside the railroad one and a half miles east of Waseca. No brick-making has since been undertaken in that vicinity. Clay suitable for this use, having no gravel, is said to occur on two or three acres of J. A. Canfield's land in section 3, Otisco, at about sixty rods northeast from his house.

Springs, chalybeate and also supposed to be salty because licked by cattle, occur in section 9, Otisco, south of the creek, being near the middle of the north side of the southwest quarter of this section. Another irony spring, somewhat resorted to by the people of its vicinity and from Waseca because of its medicinal properties, alterative and tonic, is situated northwest of the foregoing, in the southeast quarter of section 5, Otisco.

Aboriginal earthworks. The only mounds which seem to be perhaps artificial, observed or heard of in Waseca county, are two or three low, circular and dome-like heaps of earth 20 or 30 feet in diameter but only one to two feet in hight, seen in and beside the road that runs from Wilton southwest to Vivian, occurring nearly at the south line of section 10, and again in the northeast quarter of section 20, Wilton.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

BLUE EARTH COUNTY

BY WARREN UPHAM.

Contour Lines are drawn approximately for each 50 feet above the sea. Cretaceous Beds overlying the Lower Magnesian are not represented.

Explanation.

Recent — Alluvium
Modified Drift — High Terrace or Sandy and Gravel
Drift — Kames
Glacial Drift — Till, flat or undulating
Lower Mag.n — Shakopee Limestone
Jordan Sandstone
St. Lawrence Limestone

NICOLLET COUNTY
LE SUEUR COUNTY
BROWN COUNTY
WASECA COUNTY
WATONWAN COUNTY
MARTIN COUNTY
FARIBAULT COUNTY

CAMBRIA
LIME
JAMESTOWN
BUTTERNUT VALLEY
JUDSON
SOUTH BEND
MANKATO
LE RAY
LINCOLN
GARDEN CITY
RAPIDAN
DECORIA
Mc PHERSON
CERESCO
VERNON CENTER
LYRA
BEAUFORD
MEDO
PLEASANT MOUND
SHELBY
STERLING
MAPLETON
DANVILLE

MARYSBURG
MANKATO JUNCTION
Tivoli P.O.
Brick-yard
HOUSTON Winnebago Agency P.O.
Watonwan P.O.
Decoria P.O.
Belleview P.O.
Beaufort P.O.
GOOD THUNDER
Medo P.O.
Perch Lake P.O.
Myrna P.O.
EDGEWOOD
VERNON CENTER
Champion Mills P.O.
Willow Creek P.O.
Sterling Center P.O.
AMBOY
Danville P.O.
Sherman P.O.
Pleasant Mounds P.O.
Pleasant Mounds
SIBLEYVILLE
ICELAND STA.
CRYSTAL LAKE
RAPIDAN
GARDEN CITY

T. 109 N.
T. 108 N.
T. 107 N.
T. 106 N.
T. 105 N.

R. XXIX W.
R. XXVIII W.
R. XXVII W.
R. XXVI W.
R. XXV W.

Julius Bien & Co. lith.

CHAPTER XIII.

THE GEOLOGY OF BLUE EARTH COUNTY.

BY WARREN UPHAM.

Situation and area. Blue Earth county (plate 16) lies in the central part of southern Minnesota, being in the second tier of counties north of Iowa. Mankato, its largest town and the first in size within the basin of the Minnesota river, is distant about 70 miles, measured in a straight line, southwesterly from Minneapolis and Saint Paul. The length of this county from east to west is five townships, or 30 miles, and its breadth from north to south varies from 21½ to 29 miles, being least through the center of the county, from South Bend, and greatest upon its western boundary line. The Minnesota river separates this from Nicollet county. After Mankato, the towns and villages of most considerable size are Lake Crystal, Garden City, Vernon Center, Good Thunder, Mapleton and Eagle Lake. The area of Blue Earth county is 776.88 square miles, or 497,201.73 acres, of which 21,619.39 acres are covered by water.

SURFACE FEATURES.

Natural drainage. This county lies wholly within the basin of the Minnesota river, which at South Bend and Mankato turns from its southeast course and thence flows northeastwardly almost at right angles with its upper portion. The drainage from the greater part of Blue Earth county, as also of Waseca, Faribault, Martin, and Watonwan counties, is discharged into the Minnesota by the Blue Earth river, which has its mouth about one mile west of Mankato. The slopes of this county and the courses of its drainage descend from three sides, east, south and west, toward the middle of its north side. In general the county is to be described as a

nearly level, slightly undulating expanse, with mostly imperceptible slopes, which give direction to its streams. These at first flowed upon the general surface, 50 to 200 feet above the valleys, now enclosed by steep bluffs, which these streams by their long-continued wearing have excavated.

About three miles above its mouth the Blue Earth river receives from the east a tributary of nearly equal size with itself, namely, the Le Sueur river. This also has two large tributaries, the Maple and Big Cobb rivers, which unite with the Le Sueur from the south, respectively four and five miles above its junction with the Blue Earth. On its west side the only important tributary that the Blue Earth receives in this county, is the Watonwan river, which has its mouth about two miles above Rapidan Rapids, and includes within its basin of drainage all of Watonwan county and parts of the adjoining counties. Perch creek in Ceresco township, is a considerable tributary to the Watonwan from the south.

Above the mouth of Blue Earth river, the Minnesota in this county receives three other tributaries worthy of mention: Lyons or Minneopa creek, which forms the picturesque Minneopa falls; and Morgan creek and the Little Cottonwood river, which have their mouths about a half mile apart in section 16, Cambria, the most northwestern township of the county.

Lakes. Many lakes occur in this county, of which the largest are as follows: lake Wita, in the east part of Lime, having a length of one and a half miles and an area of about one square mile; lake Ballantyne, and Duck and Gilfillan lakes, in Jamestown, each about a mile long; lake Madison and Eagle lake, at the north side of Le Ray, each about three miles long and covering two square miles; lake Alice and Indian lake, each about a half mile long, in the southeast part of Le Ray; Rice lake, one and a half miles long, in southwestern McPherson; Perch lake at the west side of Medo, and Cottonwood lake in the southwest part of this township, each about two-thirds of a mile long; Rogers lake, of similar size, at the west side of Danville; Lura lake and lake Jackson, in Sterling, the former three and a half miles long, reaching south into the edge of Faribault county, and the latter about two miles long and from a half to one mile wide; a series of four lakes in the north part of Garden City township and the south edge of Judson, namely, in their order from southeast to northwest, Mills lake, Loon lake, Crystal lake, and lake Lily, of which the third is the largest, being one and a half miles long and from two-thirds to one mile wide; and Dackins, Stram, and Solberg lakes, the last, which is the largest, having an area of about a square mile, in Butternut Valley.

Nicollet named the area drained by the Blue Earth river (which he called the Mankato river) and its tributaries the *Undine region*, because of its great number of streams, "spreading themselves out in the shape of a fan," its numerous lakes surrounded by woods, and its wide, fertile prairies. The name was "derived from that of an interesting and romantic German tale, the heroine of which belonged to the extensive race of water-spirits living in the brooks and rivers and lakes, whose father was a mighty prince. She was, moreover, the niece of a great brook (the Mankato) who lived in the midst of forests, and was beloved by all the many great streams of the surrounding country."*

Topography. Nearly all of Blue Earth county has a smooth and flat or only slightly undulating surface; but this is deeply channeled along the river-courses. The south half of the county contains two small tracts of rolling land, in the northwest part of Sterling, and in the southeast of Pleasant Mound. In general, the northeast and northwest parts of the county are the most undulating. The Minnesota river at the north occupies a valley 200 to 225 feet below the general surface; and the Blue Earth

*For Nicollet's description of this region, see page 71.

river and its tributaries have cut channels that increase in depth from 50 to 100 feet along the upper portion to 150 and 200 feet near the Minnesota valley.

The central and southern portions of the county, embracing about three-quarters of its whole area, are a level, or only slightly undulating sheet of glacial drift, except that the rivers have cut deep valleys, which may be properly called channels, in the otherwise unbroken plain. This expanse includes the following townships in their order from the southeast: Danville, Medo, McPherson; Mapleton, Beauford, Decoria, Mankato; Sterling, Lyra, Rapidan, South Bend; Shelby, Vernon Center, Garden City; Pleasant Mound, Ceresco, and Lincoln.

Exceptions to the prevailing flatness of this area are the rolling tract mentioned in the northwest part of Sterling, reaching a mile or two north from the north end of lake Jackson, and rising 30 to 40 feet above the general level; the northwest part of Lyra westward from Good Thunder, and the most of Vernon Center and Garden City townships, undulating 10 to 20 feet in long slopes; and section 25, Pleasant Mound, where a group of kames, which suggests the name of the township, extends about a mile from north to south, with a width of one fourth to one third of a mile, consisting of many mounds, knolls, and short ridges, from 30 to 75 feet high, of no very notable parallelism in trend, but perhaps most frequently elongated from north to south. Their material is gravel, containing pebbles up to six inches in diameter, irregularly interstratified with sand. Boulders up to two or three feet in diameter occur rarely upon the surface of the mounds. In the south part of this section the contour charges to a more smoothed, rolling surface, with crests 20 to 30 feet high. The material here is the unmodified glacial drift or till, which also forms all the surrounding land, in prolonged low undulations. No other gravel deposits were observed in this vicinity.

Butternut Valley, Cambria, and Judson, including the part of Blue Earth county northwest from Lake Crystal, are gently undulating till, with the highest portions 10 or 20 feet above the lowest, the slopes occupying from one fourth of a mile to one mile. Isolated knolls of fine gravel and sand, 5 to 15 feet above the general level, occur rarely in these townships. Like the group of kames in Pleasant Mound, these accumulations of modified drift are believed to have been formed by streams that descended from melting ice-fields.

In the northeast part of this county, Mankato is nearly level from the top of the bluffs of the Minnesota river at the east side of the city through five miles east to Eagle Lake. To the east and north, nearly all of Le Ray, Jamestown, and the east part of Lime, are slightly or moderately undulating, with crests 10 to 25 feet above the hollows or 20 to 40 feet above the numerous lakes. Sections 19, 20, 29, and 30 of Le Ray are in massive swells 30 to 40 feet high. The northeast part of Jamestown, and the vicinity of Marysburg, are quite smooth, only undulating 5 to 15 feet in long distances.

Eroded valleys. The most notable topographic features of this county are the trough-like valleys that have been excavated by its rivers. The valley of the Blue Earth river through Shelby and Vernon Center is from 75 to 100 feet deep; in Rapidan and South Bend, before joining the Minnesota valley, its depth becomes 200 feet. Its exposures of rocks underlying the drift begin in section 13, Garden City, and extend interruptedly to its mouth. The width of this valley, between the tops of its bluffs, is mainly from a quarter to a half of a mile.

Watonwan river, tributary to this from the west, has a valley 60 to 75 feet deep through Ceresco, and from 100 to 150 feet deep through Garden City. Its only rock exposures are a few low outcrops of Shakopee limestone.

Maple river, tributary to the Le Sueur river, flows from south to north, being through the center of the county nearly parallel with the Blue Earth river and three miles east from it. In Mapleton and Sterling the valley of the Maple river is 40 feet below the general level; at Good Thunder, 75 feet; and near its mouth in Rapidan, 150 feet. The last two miles of this river, in sections 24, 13 and 12, Rapidan, have frequent exposures, and good quarries, of the Shakopee limestone.

The Big Cobb river empties into the Le Sueur about one and a half miles farther east. Its valley increases in depth from 40 feet in the southeast part of the county, to 100 feet at the quarries of Shakopee limestone in sections 19 and 18, Decoria, which are its only rock older than the drift. The Little Cobb river in Medo flows about 40 feet below the general level.

The valley of the Le Sueur river in Blue Earth county is 50 feet below the average surface at Winnebago Agency, and 75 feet below the highest points; thence it rapidly deepens, and through Decoria, Rapidan and South Bend, is from 150 to 200 feet deep. Its last three miles, in the northeast part of Rapidan, and in South Bend, have numerous exposures of rock. Excepting these and the other outcrops of rock before mentioned, the material through which the valleys of the Blue Earth river and its tributaries are eroded, is till, which encloses only few and thin layers of gravel and sand. Their bluffs rise steeply from narrow bottom lands to the nearly flat expanse of the drift-sheet. The width of the valleys thus enclosed increases with their depth from an eighth of a mile near their sources to a third or half a mile where they approach the Minnesota river.

Indian lake, three miles southwest of Mankato and one mile east of the junction of the Le Sueur river with the Blue Earth, occupies an old valley cut by the Le Sueur river, but forsaken because in their long-continued erosion the barriers between these rivers was cut through. This former valley is from 100 to 175 feet below the general level, and is about three miles long, extending from the S. W. ¼ of section 35 northeast about one mile to Indian lake and thence two miles north to the west part of the city of Mankato. Its highest point, about 50 feet above the present Le Sueur river, is southwest of the lake, which outflows northward. West of this valley the remnant of the drift-sheet between it and the Blue Earth river has been divided by erosion into two plateaus, and the railroad from Mankato to Wells passes between them in the N. E. ¼ of section 26. A third and smaller plateau lies a half mile southwest from this gap, at the east side of the mouth of the Le Sueur. The diversified scenery here and the high and picturesque bluffs along the meandering courses of all the rivers of this region are due to erosion. Along the deeper valleys this erosion has usually cut through the thick sheet of drift and reaches a considerable depth into the underlying rocks.

The valley of the Minnesota river in Blue Earth county is bounded above Mankato by bluffs which are from a half mile to one mile distant from the river. Through Mankato this distance is about a mile, but below this city, in Lime township, it becomes fully two miles. The top of these bluffs is from 200 to 225 feet above the river. This deep val ey has many exposures of the rocks that underlie the drift. About a third part of Mankato, including Front street, is on the bottomland, only 20 to 30 feet above the river, while the rest of the city occupies a gradual slope that rises 40 or 50 feet to the base of the bluffs which then ascend steeply 150 feet to the general level of the drift-sheet. These bluffs of boulder-clay nowhere present a smooth front like that which commonly bounds terraces of modified drift; but they are seamed and gullied into deep ravines by frequent rills and springs, many of which flow only at times of snow-melting or of large rains.

At the quarries and lime-kilns in the north part of Mankato the thickness of the limestone, varying in portions to calciferous sandstone and shale, all of light buff color, is about 65 feet, and this formation is underlain by white sandstone. A terrace of these strata, decreasing from two miles to one mile in width, and averaging 75 feet in hight above the river, extends thence eight miles north to Kasota; beyond which it continues at a less hight on the other side of the river through St. Peter. From Mankato to the north line of Blue Earth county this terrace is nearly two miles wide, and is bordered on the east by bluffs of till, about 150 feet high, their tops being approximately 225 feet above the Minnesota river.

It appears that the excavation in the old rocks along the Minnesota river was principally the work of pre-glacial streams; and that the erosion which has been effected here since the ice age has been mostly limited to clearing away a part of the drift with which the valley was then filled. The sheet of till appears to be spread with a somewhat uniform thickness, averaging about 150 feet, upon the bed-rocks, and doubtless at first presented a nearly level but slightly undulating, unchanneled expanse, whose lowest portions coincided approximately with the pre-glacial lines of drain-

age. The river, after excavating its valley through this sheet of glacial drift, found a channel in the underlying rocks which was eroded before the ice age. That it was not made in the recent epoch, seems to be proved by the fact that its bordering walls of rock, varying from one fourth of a mile to at least two miles apart, are through long distances concealed by drift, which alone forms one or both sides of the valley. The depth of the pre-glacial erosion was considerably below the present river, as is shown by the boring for an artesian well at the top of the river-bluff in Mankato, where the bed-rock was reached at 290 feet, or about 65 feet lower than the river.

Elevations. The following hights have been determined by railroad surveys within this county; the reference, unless otherwise stated, being to the track at depots.

St. Paul & Sioux City division of the Chicago, St. Paul, Minneapolis & Omaha railway.
Copied from profiles in the office of T. P. Gere, superintendent, Saint Paul.

	Miles from St. Paul.	Feet above the sea.
Mankato,	84.0	791
Blue Earth river, low and high water.	86.2	758–774
Blue Earth river, bridge,	86.2	795
South Bend.	87.6	808
Minneopa bridge, 68 feet above water,	89.2	863
Minneopa,	89.4	871
Summit, grade,	95.6	992
Lake Crystal,	97.3	994
Summit, grade,	102.2	1009
Iceland,	104.1	998

Winona & St. Peter division of the Chicago & Northwestern railway.
From John E. Blunt, engineer, Winona.

	Miles from Winona.	Feet above the sea.
Eagle Lake,	122.56	1012
Mankato Junction,	127.99	906
Mankato,	131.00	781

Mankato branch of the Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Mapleton,	161.4	1031
Maple river, water,	168.5	935
Good Thunder,	169.3	974
Rapidan,	175.6	979
Le Sueur river, water, 772; bridge,	177.9	825
Crossing St. Paul & Sioux City railroad,	181.3	795
Mankato,	182.5	770

The low-water slope of the Minnesota river descends 35 feet, approximately, along the north side of Blue Earth county, according to the

following elevations from the United States engineer corps. Its highest floods rise about 25 feet above this line.

Minnesota river, low water.

	Feet above the sea.
At the northwest corner of Blue Earth county, about	778
At Judson	760
At South Bend and the mouth of the Blue Earth river	756
At Mankato	752
At the line between Blue Earth and Le Sueur counties, about	743

At the points of crossing the boundary of the county, the elevation of the Watonwan river is about 960 feet; of the Blue Earth and Maple rivers, about 990; and of the Le Sueur river, about 1010. The hights above the sea of the various townships of the county, excepting their portions which have been deeply excavated by rivers, are approximately as follows: Lime, the terrace of limestone in the west part of the township, reaching about two miles easterly from the Minnesota river, 820 to 840, and the remaining two-thirds, east from the top of the bluffs, 980 to 1020; Jamestown and Le Ray, 1000 to 1060; Mankato, 975 to 1020; South Bend, plateaus between the valleys, 960 to 990; Judson and Cambria, 975 to 1000; Butternut Valley, 980 to 1020; Lincoln and Garden City, 990 to 1020; Rapidan, 975 to 1000; Decoria, 990 to 1040; McPherson, Medo, and Danville, 1025 to 1075; Beauford and Mapleton, 1000 to 1040; Lyra, 975 to 1025; Vernon Center and Ceresco, 1000 to 1040; Sterling and Shelby, 1010 to 1060; and Pleasant Mound, 1025 to about 1100. The southwest part of the last named township, which is the most southwestern of this county, appears to be the highest portion of its entire area of flat or gently undulating drift; and the kames, or irregular hillocks and short ridges of gravel and sand, in section 25 of this township, rising 30 to 75 feet above the adjoining region, and approximately 1100 to 1150 feet above the sea, are the most elevated points of land in Blue Earth county. These hillocks are thus about 400 feet above the lowest land of the county, in the valley of the Minnesota river.

The mean elevation of Blue Earth county is 1,000 feet, very nearly, above the sea; but would be 1,025, without the reduction for its eroded valleys.

Soil and timber. The soil of this county is uniformly very productive, and is well adapted for all crops which can be cultivated in this latitude. Though the land is mostly level or only slightly undulating, it is yet so intersected with water-courses that nearly all portions are well drained, giving opportunity for early sowing and planting, and preventing damage to crops by heavy rains. At the surface is a stratum of black earth usually about two feet. but varying from one to four feet in depth. It is clay, with more or less intermixture of sand and gravel, and including occasionally a stone or boulder of considerable size. Its black color has been produced by the decay of vegetation through all the years since this deposit was spread here in the ice age. The subsoil is the same glacial clay or till, without this organic matter, and of light yellowish-gray color to a depth of ten or twenty feet, below which it is darker and bluish. This difference has been produced by water and air, which to these depths below the surface have changed the carbonate of iron in this formation to the

Trees and shrubs.]

hydrated sesquioxide. A considerable proportion of carbonate of lime is present in the soil of all this region, adding much to its fertility and making the water of wells hard; but no appreciable amount of the bitterly alkaline magnesic and sodic sulphates are found.

About five-sixths of this county was naturally prairie, and supplied magnificent pasturage for the herds of the first immigrants. This region is now entirely occupied by farms, and is mainly under cultivation. It generally has a good supply of timber, which fills its numerous river valleys with a stately growth, and forms frequent groves on the shores of its lakes, and occasionally upon the general surface of the country at some distance from lakes and streams. The northeast part of the county is covered by a heavy forest, which was originally continuous but has now many clearings and excellent farms. The soil has the same character and productiveness as upon the prairies. This timbered district includes the townships of Lime (excepting the terrace in its west part), Jamestown, Le Ray, Mankato, and portions of McPherson, Decoria and Rapidan, reaching south to the Le Sueur river. It is the southern end of the Big Woods, which thence extend north nearly a hundred miles.

The trees which make up the woods of Blue Earth county are mostly more valuable for fuel than for lumber for building purposes or wooden manufactures. The white pine, which supplies the greater part of the lumber used in this region, is not found in this county. The principal trees, according to Messrs. Ellison and Ford, owners of a saw-mill in sec. 29, Le Ray, arranged in their estimated order of abundance, are the white or American elm, bass, and ironwood, very plentiful; bur oak, slippery or red elm, black ash, box-elder and willows, common; sugar maple, white ash, black oak, wild plum, June-berry, American crab-apple, common poplar or aspen, and hackberry, somewhat common; butternut, and bitternut, soft or red maple, black cherry, large-toothed poplar, cottonwood, water beech, yellow or gray birch, paper or canoe birch, red cedar, black walnut and the Kentucky coffee-tree, rare; but no red nor white oak, nor tamarack. Among the shrubs of the county are the frost grape, Virginia creeper, climbing bitter-sweet, hazel, smooth sumach, prickly ash, choke cherry, nine-bark, meadow-sweet, thorn, rose, red and black raspberries, high blackberry, prickly and smooth wild gooseberries, black currant, wolf berry, com-

mon elder, high-bush cranberry, and species of honeysuckle and cornel.

GEOLOGICAL STRUCTURE.

In the valleys of the Minnesota river, and of the Blue Earth, Watonwan, Le Sueur, Maple and Big Cobb rivers, are numerous exposures of the middle members of the Lower Magnesian or Calciferous series, these being in ascending order the St. Lawrence limestone, the Jordan sandstone and the Shakopee limestone. These formations are nearly horizontal, and they probably underlie the drift or the Cretaceous throughout the whole county; but, because of the great depth of the till, they outcrop only in the bottomlands and lower half of the bluffs of these deep valleys. Under these strata, the deep well at Mankato penetrates the St. Croix shales and sandstone, which are the lowest members of the Lower Magnesian or Calciferous series, and a great thickness of the Potsdam sandstone and shales. Over the Lower Magnesian rocks, and often filling water-worn cavities in them, Cretaceous beds of clay, and sometimes of sand and gravel, are found at several places in the county. The various geological formations to be described in the order of their age, from the oldest to the newest, are: 1. Potsdam sandstone and shales; 2. St. Croix sandstone and shales; 3. St. Lawrence limestone; 4. Jordan sandstone; 5. Shakopee limestone; 6. Cretaceous beds; 7. Glacial and modified drift.

Potsdam sandstone and shales. One of the deepest drillings ever made in the United States or the world, is that done a few years ago at Mankato, in the hope of obtaining an artesian well. This was in the southeast edge of the city, at the top of a portion of the bluffs which is commonly called "Bunker hill". Its elevation above low water of the Minnesota river is about 225 feet, making its hight above the sea approximately 975 feet. The depth of this drilling is 2204 feet, of which the greater part, reaching from about 900 feet to the bottom, is in red sandstone and shales that are believed to belong to the later part of the Potsdam period, being intermediate in age between the St. Croix group and the Cupriferous or Keweenawan series, which Prof. Winchell and the writer refer to the earlier part of this Potsdam period.

No exact record can be found to show the character of all the strata passed through and the depths at which each began and ended; but two sets of specimens of the rock encountered at successive depths are preserved, one by Mr. W. Hodapp, druggist, showing the material at eighteen

points in the section, and the other by the city council, representing twenty-nine depths. The second of these series of drillings was divided and supplied a complete duplicate set, which has been placed in the state museum. Descriptive notes were also taken of Mr. Hodapp's series, and the information gained from both is presented in the following table. Mr. G. C. Burt states that the thickness of the drift here was 290 feet, consisting mainly of the ordinary boulder-clay or till, excepting occasional layers of sand, varying from a few inches to five feet in thickness. He describes the first stratum of rock, reached at 290 feet, as a hard limestone, of light gray color.

Drillings from the deep well at Mankato.

At 310 feet, calcareous clay or shale, of greenish color.

At 330 feet, dolomite (magnesian limestone), reddish gray, somewhat siliceous.

At 380 feet, siliceous, reddish gray dolomite, containing green-sand.

At 390 feet, sandstone, with calcareous and greenish cement; containing much green-sand; the pulverized portions appearing like green shale.

At 450 feet, pinkish, somewhat siliceous dolomite.

At 453 feet, dull red quartzyte, or firmly cemented sandstone, finely granular, containing minute specks of green-sand.

At 495 feet, white, friable sandstone.

At 560 feet, fine shale, of dull pinkish color; not arenaceous, but the specimen of drillings includes intermixed sand, probably derived from a higher part of the well.

At 600 feet, like the last.

At 640 feet, yellowish, iron-rusted sandstone, with rounded, mainly siliceous grains; also including angular particles of dark red quartzyte, or hard, firmly cemented sandstone, similar to that at 453. Some of the quartz grains are covered with a thick scale, which on the outside is iridescent or sometimes black. These coated grains are occasionally aggregated into little lumps which seem to be the same with the dark red particles mentioned.

At 645 feet, similar to the last, but with less of the hard, dark red sandstone, and fewer coated grains.

At 650 feet, fine-grained sandstone.

At 660 feet, yellowish sandrock, consisting of white and yellowish siliceous grains, all rounded; and also containing occasional particles of red grit, and of greenish white, kaolin-like matter.

At 800 feet, coarse-grained, light gray sandstone.

At 850 feet, light gray sandstone, like the last, but less coarse.

At 915 feet, shale, slightly gritty, ocher-like, of dark, dull red color.

At 1010 feet, sandstone, composed mainly of grains of quartz, partly white, and partly stained with the dull red color of the last.

At 1060 feet, iron-rusted, somewhat pinkish, shaly sandstone.

At 1100, 1110, 1130, and 1140 feet, light red, medium-grained sandstone, consisting mostly of particles of white quartz, which are more or less covered with pinkish shale.

At 1150 feet, coarse gray sandstone, with mostly angular grains.

At 1240 feet, white sandstone, medium-grained, slightly red-stained.

At 1265 feet, fine, light pinkish sandstone.

At 1270 feet, coarser sandstone, reddish gray.

At 1280 feet, sandrock, having the quartz grains covered with films of red shale.

At 1320 feet, reddish, shaly sandrock.

At 1327 feet, very fine-grained, soft, pinkish gray sandstone.

At 1332 feet, sandstone like that at 1150.

At 1340 and 1342 feet, fine, reddish gray, soft sandstone, partly ochery or iron-rusted.

At 1450 feet, coarse, somewhat iron-rusted sandstone, made up largely of grains of white quartz, party water-worn, but often angular, of all sizes up to an eighth or sixth of an inch in diameter.

At 1500 feet, similar to the last.

At 1600 feet, medium-grained sandstone, reddish, in part ochery and shaly.

At 1650 feet, fine sandstone, whitish; including red and orange, apparently clayey, grains.

At 1700 feet, arenaceous, ochery shale, dull red in color.

At 1720 feet, red shale, without apparent sand-grains.

At 1810 feet, fine sandstone, with grains partly light gray, and partly dusky brown, the latter averaging slightly larger than the former. In the pulverized drillings these differently colored portions remain separate, though abundantly shaken; giving the powdered stone a mottled and streaked appearance.

At 1827 feet, medium grained, reddish, friable sandstone.

At 1860 feet, fine-grained, reddish gray, soft sandstone.

At 1872 feet, ochery and siliceous, very fine-grained, dull red shale.

At 2000 feet, red shale, with occasional grains of sand; resembling pipestone in color and fineness; but with scarcely more hardness than common clay.

At 2150 feet, similar red shale, slightly arenaceous.

At 2200 and at 2204 feet, was the same red shale, containing fine grains of white quartz.

From the depth of 915 feet in this well, to its bottom at 2204 feet, its section thus consists of sandstone and shale, mostly reddish in color, and not remarkably indurated. At 915 feet and again at 1700 and 1720 feet are beds of red shale; but from 1010 to 1650 feet, and from 1810 to 1860 feet, the specimens are siliceous, principally reddish and soft or friable, ordinary sandstone, with water-worn grains. At and below the depth of 1872 feet, the remaining 332 feet consist largely and perhaps wholly of dull red, slightly arenaceous shale, which extends below the bottom of the well. This formation of sandstone and shales, thus shown to have a thickness of about 1300 feet, appears to be, stratigraphically and lithologically, the same with the nearly horizontal red sandstone, including frequent beds of shale, which borders the south shore of lake Superior almost continuously from Fond du Lac to Grand island and again rises into view at the falls of St. Mary.

St. Croix sandstone and shales. The white sandstone in this well at 495 feet, the shale at 560 and 600 feet, and the light-colored sandstone from 640 to 850 feet, belong to the St. Croix formation, which is exposed in the bluffs of the St. Croix and Mississippi rivers. These beds, with the St. Lawrence, Jordan, Shakopee and St. Peter formations, are the western equivalents of the Calciferous, Quebec and Chazy rocks in the northeastern United States and Canada. The presence of the Potsdam sandstone and shales beneath the St. Croix in this and several other artesian wells in southeastern Minnesota, and the uniformity of the sections thus shown, demonstrate that these are two distinct formations, and make it almost certain that the St. Croix beds lie conformably upon the latest Potsdam deposits.

St. Lawrence limestone. This formation is the lowest of the three members of the Lower Magnesian series which are exposed in the valley of the Minnesota river and its tributaries in Blue Earth county. It was encoun-

tered in the Mankato well, according to Mr. G. C. Burt, at 290 feet, and extended 163 feet to the depth of 453 feet below the surface. Besides the magnesian limestone from which the formation takes its name, it includes beds of shale and sandstone, mostly calcareous; and in all these deposits it contains green-sand, sometimes in minute scattered grains, but often in considerable amount, forming so large a proportion of the rock as to make it appear like green shale, in the specimens pulverized by drilling.

The only outcrops of the St. Lawrence limestone in this county are in the valley of the Minnesota river in Judson; and, with the ledges of the same rock on the opposite side of the river, at Hebron, in Nicollet township and county, these are the first exposures of the Lower Magnesian series found in descending this valley. Along all the lower part of the Minnesota river, alternate strata of limestone and sandstone belonging to this series are frequently exposed in the bluffs and bottomland.

In Judson, at the middle part of the north side of the township, the St. Lawrence limestone is exposed along a distance of about one and a half miles, and has been considerably quarried at several places. It rises 30 to 35 feet above the river, and forms the border of a terrace covered by modified drift of the same hight and a half mile wide, which lies between it and the bluffs. Next southeast, at the east line of section 3, Judson, the road ascends to a terrace 60 feet above the river and a quarter of a mile wide, composed superficially of drift and abundantly strown with granitic and gneissic boulders of all sizes up to ten feet in diameter. Eastward this terrace sinks a little, to a hight about 45 feet above the river, and near the middle of the south part of section 2 it shows a bed of reddish arenaceous limestone, which does not, however, rise above the surface of the drift. It is believed to be the upper part of the St. Lawrence formation. Leaving this terrace at about a half mile farther southeast, the road next climbs about 125 feet in the N. W. $\frac{1}{4}$ of section 12, passing an unnamed waterfall in the Jordan sandstone, the brink of which is about 90 or 100 feet above the river.

At Mrs. G. W. Wolf's house (Judson post-office), in the S. E. $\frac{1}{4}$ of section 33, this limestone has been quarried along an extent of about twenty rods, exposing a vertical thickness of four to eight feet, the top being 30 to 35 feet above low water of the river. Another quarry on the same farm, about sixty rods farther southeast, also shows a thickness of eight feet. The section here is at top 5 or 6 feet of a very hard and durable, flesh-colored or buff, magnesian limestone, somewhat striped or mottled with greenish tints, in layers from a few inches to one foot thick, having their planes of bedding and jointage often covered with green films; then a dark greenish, sandy shale, much of it finely laminated, crumbling under the influence of the weather, 1$\frac{1}{2}$ feet; changing below to a yellowish gray calcareous sandstone, about 4 feet thick; underlain by sandy shale, which is blue for its first foot, becoming yellowish gray below, excavated only 2 or 3 feet, but reaching deeper. All these beds, and their other exposures, both in Judson and Nicollet, are nearly level, but appear to have a slight general dip, in some portions amounting to two or three degrees, to the southeast.

About a third of a mile west of Mrs. Wolf's, a hard calciferous sandrock is exposed along a little creek for a distance of a quarter of a mile, sometimes showing a vertical thickness of six feet. It is green when first uncovered, but weathers to a mottled buff, of yellowish and reddish colors. It is probably the same with the third stratum of the foregoing section, and with the arenaceous limestone and crumbling sandstone seen in the race-way of the stone mill at Hebron.

Near the ferry, about a mile east from the first described outcrops, a thickness of eight feet of this limestone is seen at John Goodwin's quarry, lying 25 feet above the river. Professor

Winchell says of this: "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 Jordan sandstone directly and conformably overlies the St. Lawrence formation, but their contact has not been observed in Blue Earth county. From the waterfall mentioned in section 12, Judson, this sandstone, gray or white, sometimes stained in small portions with iron-rust, soft and often friable, has many exposures eastward along the Minnesota valley, and also in the valleys of the Blue Earth and Le Sueur rivers.

In going southeast from this waterfall the road soon rises about 75 feet to a terrace of modified drift, upon which it runs one and one-fourth miles to a wind-mill in the N. E. ¼ of section 18, South Bend, where this terrace is called "Wind-mill bluff." Next the road descends to a terrace of the Jordan sandstone, which is frequently exposed upon a width that varies from an eighth to a fourth of a mile through a distance of two and a half miles east-southeast to South Bend, its hight above the river being about 100 feet. The beautiful Minneopa falls, in the N. W. ¼ of section 21, South Bend, four miles west of Mankato, have been produced by the excavation of Lyons creek in this sandstone which here contains hard layers near its top, but is soft below, being readily undermined by the waterfall and crumbled by weathering. The brink of this fall is about 95 feet, and the highest exposure of the rock here about 110 feet above the river, these hights being 850 and 865 feet above the sea.

Of Minneopa falls Prof. Winchell writes*: "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 stream 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 underlying 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 amphitheater 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 railroad. 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 amphitheater, where the fallen fragments are sufficiently 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 hight 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 that can be proved to be lower."

The unnamed waterfall in the N. W. ¼ of section 12, Judson, three and a half miles northwest from Minneopa, has also been described by Prof. Winchell.† "A little creek, which is dry in summer time, exposes first about two feet of coarse sandstone in its bed. Following the creek

*Second annual report, p. 150. †Same, p. 152.

Jordan sandstone.]

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. . . . . The alternation of layers here is as 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."

The top of this sandstone in the foregoing section is approximately 100 feet above the river and 860 feet above the sea. About 50 feet below this is the highest outcrop of the St. Lawrence limestone, and this is probably very near the hight of the line of junction of these formations. East from Minneopa falls the Jordan sandstone has a slight dip eastward, and in one and a half miles sinks to a hight only 65 feet above the river, or 820 feet above the sea, at David P. Davis' quarry in South Bend, where the southeast end of its terrace before described (page 426) shows a vertical exposure of 20 feet, from 65 to 85 feet above the river, of the overlying Shakopee limestone. Only the upper one or two feet of the sandstone is exposed, seen at nearly the same hight with the railroad track and on each side of it, at this quarry. At the former South Bend station, a quarter of a mile farther east, the top of the Jordan sandstone and its junction with this limestone is three feet above the railroad, 55 feet above low water in the river, and 811 feet above the sea.

A mile farther east, at the highway bridge crossing Blue Earth river, the line of junction of these formations is 40 feet, very nearly, above low water of the Minnesota river. At the quarries and lime-kilns in the north part of Mankato, this line is about 10 feet above low water, the river at this stage being there 750 feet above the sea. About a mile and three-quarters below Mankato, at a point on the river sometimes known as "Hurricane bend," in section 36 of Lime township, the Jordan sandstone reaches 45 feet above the river, being overlain by the Shakopee limestone.

The thickness of the Jordan sandstone in Blue Earth county appears to be about 75 feet In the section of the deep well at Mankato, this formation was absent, having been wholly removed, with perhaps some of the underlying St. Lawrence limestone, by pre-glacial erosion. The top of this sandstone at its most western outcrops, in Judson and at Minneopa, has a hight above the sea of 860 or 865 feet, while a half dozen miles eastward in Mankato and Lime, its top is at 760 to 790 feet. The dip eastward thus averages twelve or fifteen feet per mile, but in some portions, as from Minneopa to South Bend, it is as much as thirty feet to the mile, or about a third of a degree.

Along the Blue Earth river the Jordan sandstone and the overlying Shakopee limestone are seen at many places in the two and a half miles below the mouth of the Le Sueur river; and above this point these strata are frequently seen in the bluffs of the Blue Earth river along a distance of two miles from the new bridge in section 27, South Bend, westward to the N. W. ¼ of section 29. The course of the river in this distance passes about one mile south of Minneopa falls. Farther up the Blue Earth river no outcrops of the Shakopee limestone are found, but this sandstone continues in exposures in the lower part of the bluffs, being in sight and forming vertical banks on one side or the other along nearly the entire extent of four and a half miles, measured in a straight line, to the N. E. ¼ of section 13, Garden City, ending near the former site of Cappel's mill, half a mile below the mouth of the Watonwan river. In the two miles above the new

bridge, in South Bend, which show both the sandstone and limestone, the former reaches about 50 feet above the river, being capped by 20 to 25 feet of the latter. In sections 29 and 31, South Bend, this Jordan sandstone declines in hight from 50 to 40 feet; at Rapidan Rapids its hight is 30 feet; and beyond this its elevation above the river is diminished to only a few feet at its last outcrops, in the east edge of Garden City township. By comparison with the descent of the river, it appears that the top of the sandstone is nearly level in these exposures, having about the same hight as at Minneopa falls and in Judson. All these outcrops have the ordinary characters of the Jordan sandstone, being white or gray, soft and mostly friable, in horizontal beds from a few inches to one or two feet thick. At the bend of this river, in the south edge of section 21, South Bend, where this formation rises on the north side to a hight of about 50 feet and is overlain by 20 feet of Shakopee limestone, the upper part of the Jordan sandstone contains occasional flattened masses, two or three inches long and an eighth to a fourth of an inch thick, of a white powder, which when wet becomes a sticky paste.

In the north bluff of the Blue Earth river, within a short distance above the bridge in section 27, South Bend, and about three-quarters of a mile above the mouth of the Le Sueur river, is the place where the Sisseton Indians, as stated by Featherstonhaugh, obtained a bluish green pigment which was held in high esteem. Nicollet says: "It is massive, somewhat plastic, emits an argillaceous odor when breathed upon; color bluish green; easily scratched with the nail, when formed into hardened balls. The acids have no action upon it; it is infusible before the blowpipe, but loses its color and becomes brown. This color is due to the peroxide of iron" [otherwise combined chemically until changed by the blowpipe flame], "which it contains in the proportion of ten per cent. at least. It contains no potash, and but a small proportion of lime." This was found in a shaly layer at the line of junction of the sandstone and limestone; but it occurred here only in small amount, and had been nearly exhausted before the time of Featherstonhaugh and Nicollet.* In our exploration it was carefully looked for, but nothing of this kind worthy of note was seen. Somewhere in this neighborhood, either in the bluffs of the Blue Earth or Le Sueur river, as much as four thousand pounds of a similar green or blue earth, perhaps from this horizon of the Lower Magnesian, but more probably from the Cretaceous shales or clay common in this region, being supposed to be an ore of copper, was gathered and shipped to France by Le Sueur, in the years 1700 and 1701. Further reference to this subject will be found on a following page, in the description of the Cretaceous deposits. From this earth, the location and nature of which remain in some uncertainty, the name of the river and thence of the county is derived.

On the Le Sueur river the Jordan sandstone is frequently exposed along a distance of one and a half miles next above the bridge of the railroad from Mankato to Wells, in section 35, of South Bend and Mankato, and section 2, Rapidan. In ascending the river the first of these outcrops is found four miles southwest from Mankato, and about a half mile south from the site of Red Jacket mill, which was recently burned. Here this sandstone forms a perpendicular bank 20 to 30 feet high and an eighth of a mile long, lying at the northeast side of the river next above the railroad bridge. It is a levelly stratified, but often obliquely bedded, friable, white sandstone. Its top here is 800 feet above the sea. Overlying it is a thickness of about 60 feet of irregularly interbedded clay and sand, with ochery and iron-rusted layers, probably Cretaceous deposits, and above these glacial drift forms the upper part of the bluff. The Jordan sandstone here presents a notable peculiarity which has not been observed in its outcrops elsewhere, excepting at the point before mentioned on the Blue Earth river. This is the existence of frequent cavities in the sandstone, filled with masses of white friable clay, as described by Prof. Winchell, "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." At the iron bridge, near the south line of section 35, South Bend, about half a mile southeast from the last, this sandstone rises vertically to a hight of about 20 feet in the bank on the west side of the river, and is overlain by 20 feet of Cretaceous clay and sand, succeeded by 10 feet of somewhat ferruginous drift. About a half mile farther southeast, on land of O. Halberg, near the center of the east half of section 2, Rapidan, a short ledge of Jordan sandstone rises 15 feet or more above the river in its southwest bank; and the opposite bank, at 20 to 40 rods up stream from the last, shows this rock to a hight of 6 or 8 feet, overlain by 20 to 25 feet of Cretaceous clays, and capped by drift, the

*See historical notes respecting this locality, pp. 60 and 72; and of Le Sueur's copper mine, pp. 16, 59, and 71.

Shakopee limestone.]

whole bluff being 50 to 75 feet high. The Shakopee limestone, next in geological order above this sandstone, was not found in place on this part of the river, but about six rods northwest from the sandstone outcrop on O. Halberg's land, large blocks of this limestone lie at the base of the bluff beside the river, and have probably fallen from a ledge above; yet the steep, wooded face of the bluff now exhibits only drift.

No fossils have been detected in the St. Lawrence limestone or Jordan sandstone in Blue Earth county.

Shakopee limestone. This member of the Lower Magnesian series, and the sandstone just described, which it conformably overlies, both having a very nearly level stratification, together make the rock-bluffs of the Minnesota and Blue Earth rivers in the townships of South Bend, Mankato, and Lime. Other outcrops of the Shakopee limestone, without exposures of the underlying formation, occur on the Watonwan river at and close below Garden City, and on the Maple and Big Cobb rivers within their last two miles. This limestone has been quarried at many places, and has a high value for building purposes and for the manufacture of lime and hydraulic cement.* It is mainly a compact and hard, thick-bedded, somewhat siliceous dolomite or magnesian limestone, of light buff color, often mottled with slightly contrasted reddish and yellowish tints. The layer which is burnt for lime at Mankato, situated in the upper part of this formation, is sparingly fossiliferous.† Professor Winchell, from an examination of the Mankato quarries and of the river bluffs for several miles below, gives the following general section, in descending order:‡

Section of the Shakopee limestone in Mankato and Lime.

1. Porous magnesian limestone, not used	4–6 ft.
2. Loose, friable sandstone	2–4 ft.
3. Magnesian limestone burned for lime	2 ft.
4. Calciferous sandstone, in heavy beds, of various grain and texture, sometimes mottled, quarried for building	30 ft.
5. Upper shale bed, arenaceous and mottled with red	2–3 ft.
6. Calciferous sandstone, generally used as a cut stone, compact and even grained,	4 ft.
7. Rough and irregular magnesisn limestone, somewhat arenaceous, but unfit for cutting	10 ft.
8. Lower shale bed; very much the same as the upper	2 ft.
9. One heavy bed, generally good for cut-stone, becoming light blue on deep quarrying	3 ft.
10. Irregular and sandy bed; more or less cavernous and porous, with lenticular stratification, its lower three or four inches apparently broken; fine-grained, and stained with iron	3 ft.
11. Jordan sandstone, seen about	15 ft.
Total of the Shakopee limestone, about	65 ft.

*See the chapter on building stones, p. 166. The quarries of this stone, and analyses of it, are noted in a later part of the present chapter.

†In the quarries at Mankato, and especially in that of the Standard Cement company, which is in the lower part of the formation, a handsome *Lingula* is occasionally found. This shell is about half an inch long, of acuminate-obovate outline, with concentric striæ.

‡Second annual report, p. 145.

This is approximately the thickness of this formation exposed to view in its outcrops through its whole extent of sixty miles along the Minnesota river. The quarries at the north end of Front street in Mankato exhibit the first nine numbers of the foregoing section, with a very slight dip northeast. The terrace, 75 feet above the river, one to two miles wide and ten miles long, made by the Shakopee limestone, underlain by the Jordan sandstone, extending from Mankato north through Lime and Kasota to St. Peter, has been described in speaking of the surface features of this county.

Opposite to Mankato this limestone and the underlying sandstone form the lower half of the river-bluff in Belgrade, Nicollet county. A mile west of Mankato, the Shakopee limestone makes the small plateau called Sibley mound, which lies at the east side of the Blue Earth river close to its mouth; and the similar plateau just opposite, on the west side of this river, to which the name L'Huillier mound has been given, consists of the same limestone with a considerable thickness of Jordan sandstone at the base. These mounds together reach about a third of a mile from east to west. The hight of the former is approximately 50 feet, and of the latter 75 feet, above the bottomland, which is five to ten feet above the Minnesota and Blue Earth rivers. Channels cut here by these streams, perhaps since the ice age, have separated these mounds from the Belgrade bluffs and from each other.*

Professor Winchell reports the following

Section of L'Huillier mound.

1. Pebbles and soil at the brink of the bluff ..... 2 ft.
2. Dislodged, broken layers of Shakopee limestone ..... 35 ft.
3. Crust of iron and manganese ..... 2–4 in.
4. Green clay, or shale, becoming white toward the top and on the outer surface; evenly laminated, the laminæ passing up into the white color. This is unconformably overlain by masses of dislodged Shakopee limestone, the under surface of which is crusted and rounded by water action. It also ascends between openings in these masses ..... 3 ft.
5. Perpendicular cliff of Jordan sandstone, showing irregular seams and laminæ of green shale, also small balls and bunches of curious shapes, sometimes conforming to the general sedimentation, and somewhat also to the false bedding, so called. These thin deposits of green clay are fourteen feet below the general bed of green clay (No. 4) above ..... 10–15 ft.
6. Talus, covering the Jordan sandstone, and reaching to the alluvial flood-plain .. 25 ft.

The same strata outcrop in many places through a distance of six miles west-southwest from Mankato, occurring in the bluffs of the old channel of the Le Sueur river between three-fourths of a mile and one and a half miles north of Indian lake, in the bluffs of Blue Earth river a half mile farther west, in the terrace at South Bend, as before mentioned, thinly covered by modified drift, and again in the bluffs of the Blue Earth river a mile south of South Bend and Minneopa. The top of the Shakopee limestone in these exposures has a hight 75 to 100 feet above the Minnesota river, or about 825 to 850 above the sea; and the glacial drift, lying on this limestone and forming the higher part of the bluffs, has its top 200 to 225 feet above the river, at which elevation its slightly undulating expanse forms table-lands on each side of the valleys and thence reaches with imperceptibly ascending slopes to the east, south and west, beyond the boundaries of the county.

Like this sheet of drift, the underlying rocks appear to have a nearly level but slightly sloping top, which may have been the surface of this region before the ice age, but more probably was planed and brought to its comparative uniformity in hight by glacial erosion. In Blue Earth county the rock-surface, uncovered along the Minnesota valley, makes the terrace of Jordan sandstone in Judson and thence to Minneopa falls, and its continuation capped by Shakopee limestone at South Bend; is exposed, overlain by drift, in the bluffs of the Blue Earth and Le Sueur rivers, and of the Minnesota river in Belgrade; forms the L'Huillier and Sibley mounds; and, below Mankato, reaches in a broad terrace to Saint Peter. The Minnesota river, after cutting through the overlying 125 to 150 feet of till, found here an old valley which had been channeled in these rocks by pre-glacial streams.

*The east mound derives its name from the encampment near it of the troops under the command of Gen. H. H. Sibley, on their return from suppressing the Indian outbreak in 1862. L'Huillier was the assayer who examined Le Sueur's copper ore, and from whom his fort was named (see page 17).

At Garden City the Shakopee limestone is exposed on a small island and in the left bank of the Watonwan river, close below the dam and mill. The area of these exposures is about four rods square, and their hight three to five feet above the water. Professor Winchell records the occurrence of a species of *Euomphalus* in this stone, apparently the same fossil that was described and named *Straparollus Minnesotensis* by Owen. This rock has nearly the same aspect as at Shakopee, having frequent cavities, and being sometimes a breccia. It lies in thick beds which are irregularly tilted and dip synclinally 10° to 20° from both north and south into the river. The probable explanation of this is that this limestone, at first horizontally stratified, has been fractured by the removal of a part of the underlying friable Jordan sandstone, through pre-glacial drainage into a river lower than that of the present time. Another outcrop of this limestone is found a third of a mile northeast from Garden City, on land of the S. M. Folsom estate. It is at the northwest side of the Watonwan river, and is principally covered with drift, being seen at only a few small excavations upon an area fifty feet long and fifteen to thirty feet wide, adjoining the river and gradually rising about five feet above it. It has layers one foot or more in thickness, and has been somewhat quarried.

The valley of the Le Sueur river has an outcrop of this limestone on land of Andrew Algren, in the N. E. ¼ of section 11, Rapidan, being on the southwest side of the Le Sueur about two-thirds of a mile below the mouth of Maple river. The ledge seen here reaches five feet vertically, and is in level beds six inches to one foot or more in thickness. It is about twenty rods from the river and fifteen to twenty feet above it.

On the Maple river the Shakopee limestone is quarried at many places within a mile above its mouth, and occasional low outcrops of it are found along the next mile, to the south part of the N. W. ¼ of section 24, Rapidan. At these quarries the stone is a compact, light-buff dolomite, of nearly uniform texture and color, in horizontal layers one to three feet thick, reaching from the level of the river to hights twenty to thirty feet above it.

On the Big Cobb river this formation outcrops and is slightly quarried three-fourths of a mile and one and one-fourth miles above its mouth. The first of these localities is on land of Matthew Ryan, in the S. E. ¼ of section 18, Decoria, where this stone makes a terrace which extends about a quarter of a mile in the bottom land, being twenty to twenty-five feet above the river and seventy-five feet below the top of its bluffs and the general surface of the drift. The highest points of the limestone here are fully thirty feet above the river, and have the form of isolated mounds of horizontal strata, which have been spared, while the continuation of the same beds has been removed, by the agencies of weathering and erosion. These mounds rise ten to fifteen feet perpendicularly or often with overhanging sides. A similar picturesque weathering of this limestone, forming many such mounds five to ten feet high, was also seen four miles north of Mankato, on land of Joseph Kunz, in the S. E. ¼ of section 19, Lime. At Mr. Ryan's quarries, near the south end of the exposures of rock on his land, its hight at the east side of the river is about twenty feet and at the west side ten feet, their distance apart being ten or twelve rods. This stone has the same characters as in the quarries of Mankato and Maple river. It lies in beds which are from one to four feet thick, their stratification on the east side of the river being nearly level, but on the west side dipping 5° to 10° west. About a half mile farther south, on land of A. W. White, in the N. E. ¼ of section 19, Decoria, the Shakopee limestone is again exposed, forming a vertical cliff which rises from the level of the river to about thirty-five feet above it, in its left (here the northern) bank. It holds this hight for an extent of about ten rods, and continues with decreasing hight as much farther westward. At its west extremity this limestone is overlain by Cretaceous beds; but mainly this ledge is covered by till, which reaches seventy-five feet above the river.

The elevation above the sea of the outcrops of Shakopee limestone on the Watonwan river at Garden City and on the Maple and Big Cobb rivers is 875 to 900 feet, being about fifty feet higher than the top of this formation in Mankato and Lime, eight to twelve miles farther north.

Cretaceous beds. The only deposits found in Blue Earth county above the foregoing Lower Magnesian strata and below the drift are beds of clay, sand and sandstone, and rarely gravel, which are believed to have been

formed in the Cretaceous age. Similar formations, containing characteristic Cretaceous fossils, occur in other portions of this state, toward the east, north and west, and have a great development farther west in the region drained by the upper Missouri river. No fossils have been found, however, in any of these deposits in this county, though they are exposed in many localities and present much diversity in material. They often occur in the ordinary manner of stratified sediments, unconformably overlying eroded surfaces of the Jordan and Shakopee formations; but another frequent mode of occurrence is in large water-worn cavities and fissures of these rocks, principally of the Shakopee limestone. Before the deposition of the beds here called Cretaceous, these Cambrian rocks at many places in the Minnesota valley had become channeled by rivers and sculptured into irregular basins, pot-holes, and hollows, from five to twenty-five feet in depth, often partly covered by overhanging walls. These pocket-like cavities are smoothly water-worn, and their surface is often thinly coated with iron ore. Within them clay has been sifted and packed so as to fill their irregular spaces, frequently covered in part by the limestone. The crust of iron ore (limonite with a little manganese oxide) was probably formed, however, since the clay was deposited. It should be added that the clay was doubtless of greater depth and extent at some former time; so that all the ore-covered surfaces observed may have become thus encrusted while enveloped in the clay. This deposit is, more strictly speaking, a very fine sandy and clayey silt, greenish or bluish, weathering white, horizontally bedded, or conforming somewhat to the shape of the hollow that holds it.

The following descriptions of these Cretaceous beds are given in geographic order, as they are found in descending the Minnesota valley, and afterward their exposures on the Blue Earth, Watonwan, Le Sueur, Maple and Big Cobb rivers are successively noted.

Within the Minnesota valley, in this county, the first occurrence of deposits probably of Cretaceous age is on land of Edward Rowe, in the west part of section 23, Cambria, where a conglomeritic sandstone, much broken into masses of various sizes up to eight or twelve feet long and five or six feet thick, covers a small area beside the river, having about the same hight with the flood-plain. It is underlain by a fine blue clay, without gravel or pebbles. Comparing these with the other beds of similar character in this region, we find outcrops of the sandstone on the opposite side of the river, in Nicollet county, one mile below and about two miles above this point. At the second of these localities some of its layers contain fragments of wood, or lignite, and angiospermous leaves. The underlying clay appears to be the same with that which else-

where fills cavities in the Shakopee limestone. This order of deposition, first, clay, and later, sand and sandstone, is also found in these beds on the Maple river.

In South Bend, at David P. Davis' quarry, the section on the north side of the railroad is, at the top, fifteen to twenty feet of Shakopee limestone, in layers only a few inches thick, because of weathering, for its upper three to five feet, but below forming beds from one to three or four feet in thickness; containing many crevices and hollows up to twenty feet in diameter and ten to twenty feet deep, filled with a compact clay, mainly white or gray, but in a few places of a brick-red and elsewhere bluish green color (Fig. 23). Next below, this limestone appears, deceptively, to

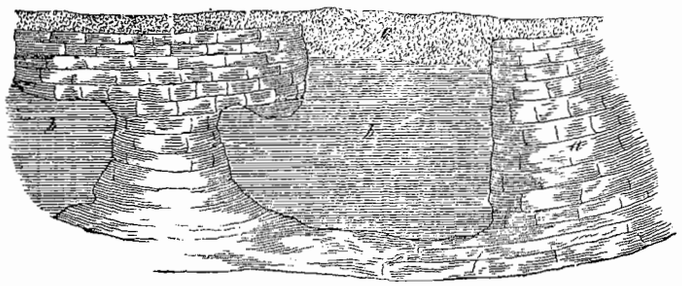


FIG. 23. CRETACEOUS CLAY IN HOLLOWS OF THE SHAKOPEE LIMESTONE, SOUTH BEND.
a. Shakopee limestone. *b*. Cretaceous clay. *c*. Drift.

be underlain by a nearly levelly stratified bed of this clay, four to five feet thick, lying on the Jordan sandstone, which forms the lowest one to two feet of the section. The horizontal bed of clay here is probably of small extent, filling a space from which the upper part of the friable sandstone had been excavated by running water. South of the railroad track, this stratum of gray and green clay, two feet thick, becoming gray sand below, also two feet thick, is seen along a distance of fifteen rods, overlain by limestone debris, and underlain by the Jordan sandstone.

Professor Winchell has described* an instructive section of the Shakopee limestone and its associated deposits of this clay, as observed in a cut near the railroad bridge which crosses the Blue Earth river about a mile above its mouth. "This cut is perhaps 70 feet above the river, the

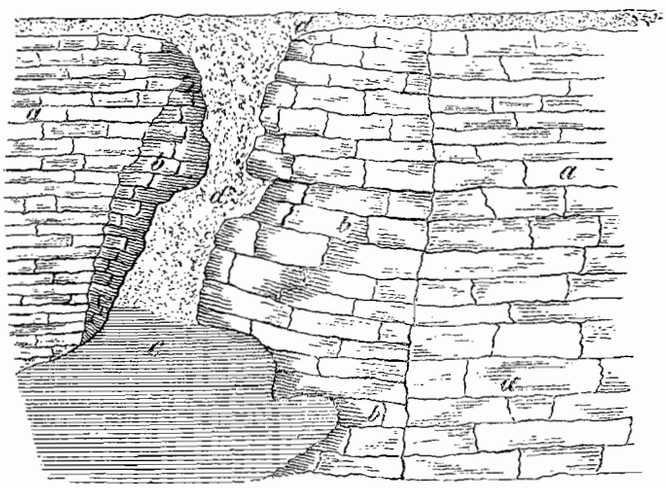


FIG. 24. SECTION NEAR THE RAILROAD BRIDGE, MANKATO.
a. Shakopee limestone, cut by the grading of the railroad. *b*. Weathered surface of same.
c. Cretaceous clay, greenish blue, bedded. *d*. Drift.

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 rail-

*Second annual report, p. 178.

road cut shows a mixture of Cretaceous clay with the Cambrian, the top of the whole being thinly and irregularly covered over and chinked up with coarse drift. The Cambrian 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 Cambrian 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 Cambrian 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 limestone 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 surface of the blocks, yet it runs down between the Cretaceous clay and the body of the rock."

Another deposit of greenish clay (Fig. 25) similar to the two last described, enclosed in a cavity of the Shakopee limestone and in part appearing to be a stratum overlain by it, was noted beside the carriage road from South Bend to Mankato close east of its bridge over the Blue Earth river.

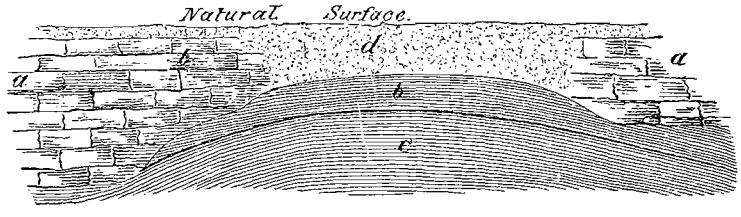


FIG. 25. CRETACEOUS CLAY BENEATH THE SHAKOPEE LIMESTONE, MANKATO.
a. Shakopee limestone. *b.* Bedded greenish clay, weathering white, but little sandy. *c.* Sandy, bedded greenish clay. *d.* Drift, mostly coarse fragments of Shakopee limestone.

In the S. W. ¼ of section 20, Lime, the quarry of J. R. Beatty & Co. exhibits a thickness of twenty to twenty-five feet of the Shakopee limestone. The top of this ledge is waterworn and hollowed in shallow pot-holes. Near the middle of the quarry face, as it was at the time of examination, these waterworn cavities reach to a depth of fifteen feet, their sides being in part encrusted with an iron-rusty scale, an eighth to a half of an inch thick. They are filled with very coarse ferruginous gravel, much waterworn, so that sometimes its pebbles up to three or four inches in diameter are almost perfectly spherical. In some of these crevices scanty traces of white clay occur with the gravel, the former being probably Cretaceous, while the latter seems to be older than the glacial drift, and may be Cretaceous or of earlier date, possibly representing the period in which these hollows were eroded. Close west of this quarry is found a thick bed of whitish, very fine earth (analysis 2, page 438), containing too little clay for brick-making.

Professor Winchell writes as follows respecting these probably Cretaceous deposits at localities recently examined by him near Mankato. "At the quarry of the Standard Cement company, lately opened in the east bank of the Blue Earth river about a third of a mile south of the railroad bridge, the Shakopee limestone is separated from the Jordan sandstone by a course of light green or often nearly white shale or clay, highly siliceous and aluminous, having a thickness of about three feet. The hydraulic qualities of the Shakopee limestone seem to be associated with the occurrence of this bed of shale, and to be altogether an accidental and local character. The formation has before been known to be somewhat hydraulic, but here this quality is so far extended as to make a valuable source of hydraulic lime. In the Shakopee limestone here are also numerous pits and gorges, rounded off with age and crusted over with a ferruginous scale

that is sometimes as much as three inches thick. These old crevices cut across the strata and pass from top to bottom of the formation. They are filled with the same, or a very similar, light-colored clay, the same being continuous from the clay between the Shakopee and Jordan upward through the openings to the top of the limestone strata, and there spreading out, in imperfectly laminated beds, *over the similarly rusted upper surface* of the Shakopee. The bed of clay under this limestone is known to extend back from the bluff of the river about eighty feet, and seems to be *in situ* and of Cambrian age. Yet it seems not to be confined to this place between the Jordan and Shakopee formations, where the most of it is seen; and as it occupies eroded cavities and all seams and small openings within the Shakopee, and also overlies that formation, apparently unconformably, it has been considered of Cretaceous age.* Prof. A. F. Bechdolt, of Mankato, regards it as a result of chemical change in the overlying St. Peter sandstone and the underlying Jordan sandstone; but it more probably resulted from a local degradation of the hydraulic Shakopee limestone, through long sub-aerial exposure, if its origin be at all attributable to such agents."

"This white clay appears frequently at the same horizon, overlying the Jordan sandstone, at points in the Le Sueur valley. It was examined on the land of S. F. Alberger, along the banks of the Le Sueur in section 35, Mankato, where it lies about twenty feet above the river at the railroad crossing, and is overlain by a series of confused, concretionary and lenticular beds of sandstone, with alternations of clay, passing upward into a rusty conglomerate and crag-like rock, and into a sandstone containing traces of wood, similar to that seen in Fillmore and Mower counties, and at Fritz' quarry in Nicollet county, evidently of Cretaceous age. In ascending the river from the railroad crossing, the water line rises over the underlying sandstone, and reaches this clay bed. It is seen to become red in some places, and often somewhat gritty. The valley of the Le Sueur in this vicinity, and its tributary valleys, also the deserted channel through Indian lake, to which Prof. Bechdolt has called attention, are wrought principally in Cretaceous strata, overlain by a deposit of drift clay which shows, in numerous instances, the effect of water in its deposition."

Professor Winchell summarizes, in descending order, the following

General section of the Cretaceous in the Le Sueur valley, sec. 35, Mankato.

1. Conglomerate and sandstone; with traces of woody fiber; in oblique and lenticular stratification; the probable equivalent of fossiliferous strata at Fritz' quarry in Nicollet county, and of the sandstone a few miles southwest of New Ulm.....20-30 ft.
2. Potter's clays and fine sand, irregularly and lenticularly interbedded.....20-30 ft.
3. Rusty and confused, concretionary sandrock.....20-30 ft.
4. White (kaolinic?) clay; within of a light greenish color; becoming red and arenaceous in some places..... 6-8 ft.
5. Jordan sandstone, seen ..... 20 ft.

Professor Bechdolt states that a slab of rusty sandstone was found some years ago on the bluff back of Mankato, containing fossil leaves resembling *Salix*; also, that a small shark's tooth was picked up in the alluvium at the mouth of the Blue Earth river; and that at any time small pieces of lignite coal may be found in the alluvium at the mouth of the Blue Earth, brought down by the latest freshet from the valley. All these were doubtless derived from Cretaceous formations.

On the Blue Earth river above the localities already mentioned, Cretaceous beds are reported by Mr. John Leiberg in the left (north) bank of the river about twenty rods below the new bridge in section 27, South Bend, being a somewhat sandy, deep green shale, exposed along an extent of about a hundred and fifty feet, rising in a flattened anticlinal about five feet above the line of low water; overlain by a bed of dark, ferruginous gravel, about ten feet thick, containing concretionary iron ore (limonite); above which is light gray or white, friable sand or sandstone, about thirty feet thick; succeeded by till, which forms the upper part of the bluff.†

At the east end of the Rapidan Rapids bridge, the cliff of Jordan sandstone, thirty feet high, is overlain by ten feet or more of interstratified clay, sand and fine gravel, referred to the Creta-

*See the second annual report, pp. 176–181; also the eighth annual report, p. 109.

†It seems quite likely that this is the site of Le Sueur's copper mine, as it agrees well with Penicaut's description (See pages 17 and 428).

ceous age. The layers of clay are mostly white, but sometimes red; and the sand and gravel are occasionally cemented with iron ore. Above these the bluff consists of till, and rises to a hight about 150 feet above the river.

A sandstone, which may belong to either the Jordan or St. Peter formations of the Lower Magnesian group, but seems quite likely to be Cretaceous, and other beds more certainly referred to this later age, occur in the banks of the Watonwan river at Garden City, southwest and north of the fair-ground, rising fifteen to thirty feet above the river. Of these deposits Prof. Winchell writes*: "It [the sandstone] is here associated with more or less clay, crag, and iron and lime cement. A heavy deposit of drift crag [cemented gravel, probably Cretaceous] may be seen on E. T. Norton's place, and also . . . . . opposite Mr. Norton's. Under the crag is clean white sand. A little further 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. . . . . It lies 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 the fair-ground], 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."

On the Le Sueur river close above the railroad bridge the Jordan sandstone, described on page 428, is overlain by about sixty feet of clay and sand or sandrock layers, irregularly interstratified. In the lower portion the clay is mostly white, but at one place is red and by being washed down paints a portion of the bluff a few feet in width. This is about a hundred feet southeast of "chalk run," a gap in the bluff which has its name in allusion to these white and red clays. The sand is mostly ferruginous, and is cemented by iron-rust. These beds rise from thirty to forty feet above the railroad bridge, which is 825 feet above the sea. The clay which is used at Mankato for the manufacture of pottery is obtained at this place, southeast of the railroad and about fifteen feet above the level of the railroad grade. In the bank four rods east of the railroad bridge, the following descending section was noted. It is embraced in No. 2 of Prof. Winchell's general section already given.

Section of Cretaceous beds near the Le Sueur river railroad bridge, sec. 35, Mankato.

1.	Coarsely rocky drift	4–10 ft.
2.	Stratified gravel and sand, ferruginous, farther eastward iron-cemented	3–5 ft.
3.	Dull gray, horizonally stratified clay	1–2 ft.
4.	Dull gray, horizontally stratified sand	4 ft.
5.	Second layer of clay, like No. 3	1½–2 ft.
6.	Second layer of sand, like No. 4	4 ft.
7.	Third layer of clay, like No. 3	1½–2 ft.
8.	Third layer of sand, like No. 4, seen	1 ft.

The top of the last of these layers is six feet above the railroad, and is higher than the white and red strata which overlie the Jordan sandstone in the adjacent river-bluff. At the iron bridge, about a half mile farther up this river, the Jordan sandstone is overlain by twenty feet of clayey and sandy, nearly levelly stratified Cretaceous strata, of gray and whitish color, in many portions containing small lumps of white clay. In the east part of section 2, Rapidan, the northeast bank of the Le Sueur river shows a few feet of Jordan sandstone at the base, on which rest white and gray Cretaceous clays, closely like the deposits which fill cavities of the Shakopee limestone in South Bend and Mankato, nearly horizontal in stratification, having a thickness of twenty to twenty-five feet and exposed along a distance of about twenty-five rods. These strata are reddish in a few small and inconspicuous portions. Above them the upper part of the bluff is drift. Again, an eighth of a mile farther south, Cretaceous strata of similar character form the bank on the southwest side of this river along a distance of nearly twenty rods, but at the time of observation were much obscured by falling down. This bluff is 40 to 75 feet high, with ascent toward the south, all above 30 to 40 feet being drift.

On the Maple river are numerous exposures of sand or sandstone and clay, which closely

*Second annual report, p. 134.

resemble the beds described in Garden City. At Columbus Ballard's quarry, on the west side of the river near its mouth, in the N. E. ¼ of the S. W. ¼ of section 12, Rapidan, the west part of the ledge of Shakopee limestone which is worked, is overlain by twenty feet of Cretaceous clays, mostly whitish, in some parts irony, and rarely reddish. Here the limestone has a hight of only ten feet, but it rises twenty feet above the river a hundred feet farther east. Along the last two miles of this river, in the northeast part of Rapidan township, Prof. Winchell describes* "a friable, white sandstone, ... underlain by about two feet of a greenish blue clay, and associated with concretionary and irregular sheets of brown hæmatite. 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 limestone, but unconformable with its bedding. At one place the following section can be made out:

1. Alluvium ..... 15 feet.
2. Irony crag and impure iron ore ..... 2 feet.
3. Greenish bedded clay ..... 2 feet.
4. Strata of Shakopee limestone, more or less stained and encrusted with iron 4 feet.

"These parts are arranged, relatively to each other, as shown in Fig. 26.

FIG. 26. SECTION IN THE BANK OF MAPLE RIVER, RAPIDAN.

"The white sand . . . is in some way associated with the 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. . . . At other places, a little above the point of the foregoing section, the iron and sand are found irregularly mingled, the iron occurring 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 farther up, the 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 the 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 resemblence 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 Shakopee limestone*, separated only by a thin bed of greenish blue shale. . . . At a point a little further along, this sand is more persistent, and shows horizontal bedding, by reason of the manner of its falling down from the bluff. Beds, 3–8 inches."

At the quarries of Shakopee limestone on the Big Cobb river in sections 18 and 19, Decoria, about one and a half miles east from the last, are other Cretaceous beds. In two hollows of this

*Second annual report, p. 132.

limestone on the west side of the river at Ryan's quarry are deposits, one of white, and the other of red clay, each two to three feet thick. The west end of White & Curtis' quarry is covered by Cretaceous accumulations which are in turn overlain by drift. The section from top to base of the bluff here is as follows:

Section in the bank of the Big Cobb river, N. E. ¼ of sec. 19, Decoria.

1. Yellowish sandy till..... 10–15 ft.
2. Dark bluish till..... 30 ft.
3. Red and yellow clay, seen at two places, each having an extent of only a few feet..... 2 ft.
4. Ferruginous, sandy shale, with much interstratified loose sand, some of these beds being mainly white, others dark, while the greater part have an iron-rusted color, and are more or less cemented by limonite; visible along a distance of 25 rods, from the extremity of the Shakopee limestone southwesterly to the ford and foot-bridge; in thickness, about.... 10 ft.
5. Incoherent, irregularly stratified sandstone, straw-colored or nearly white, containing infrequent specks of a snowy white powder; exposed at 12 to 18 feet above the river, for a distance of only 25 feet, being obscured below and elsewhere by the fallen talus..... 6 ft.
6. Shakopee limestone, farther east rising 35 feet in a perpendicular cliff from the river, here .....10–15 ft.

Numbers 3, 4 and 5 are believed to be Cretaceous, but no fossils were seen in any of these strata.

Analyses of Cretaceous clays from the vicinity of Mankato.

Five analyses, shown in the table below, have been made for this survey, of samples of the very fine, more or less clayey silt which has been described in the foregoing pages in respect to its manner of occurrence.

The first of these analyses (No. 67, eighth annual report) was made by Prof. S. F. Peckham, and is the clay or shale filling hollows of the Shakopee limestone in the west part of Mankato. Prof. Peckham remarks: "Its composition places it with orthoclase, although it has the physical properties of kaolin. It is chemically a slightly decomposed feldspar, while it has the appearance and some of the properties of clay. It, however, appears to contain too much iron to admit of its being used for white ware, although a practical test is often required to definitely settle the value of clays for such purposes."

The second analysis (No. 75, tenth annual report) was by Prof. J. A. Dodge, and is from a nearly white clayey bed of considerable extent, which has been tried unsuccessfully for brick-making, near the quarry of J. R. Beatty & Co., in section 20, Lime. "This was pulverized, without grinding up the particles of gritty matter that were to some extent intermixed with it; the powder was then mixed with distilled water, the suspended portion poured off and allowed to settle for a day or two; the settled portion was then collected, dried at 212°, and submitted to analysis by the common methods for silicates."

The third (No. 138, twelfth annual report) was by Mr. C. F. Sidener, and is a nearly white, very fine-grained, somewhat friable earth, in the lower part of the succession of Cretaceous strata in section 35, Mankato (from the east bluff of the Le Sueur river close above the railroad bridge, in No. 4 of page 435).

The fourth (No. 139, twelfth annual report), by Mr. Sidener, is from the same locality with the last, and is the red ochery clay which was mentioned on page 436.

The fifth analysis (No. 146, twelfth annual report), also by Mr. Sidener, is the clay or shale observed between the Shakopee limestone and the Jordan sandstone in the L'Huillier mound (No. 4, page 430). Like No. 1 of this table, but in less degree, "it is rather remarkable for containing so much potash, which probably exists in it in the form of finely divided potash feldspar."

	1.	2.	3.	4.	5.
Silica, $Si O_2$	70.10	87.70	93.65	73.34	68.70
Alumina, $Al_2 O_3$	16.99	7.24	2.15	14.75	18.04
Lime, Ca O	.....	0.67	0.20	0.28	1.24
Magnesia, Mg O	.....	0.07	0.12	0.05	0.56
Potassa, $K_2 O$	10.69	0.49	traces	traces	5.28

Soda, Na_2O		3.17	traces	traces	0.24
Ferric oxide, Fe_2O_3	traces	traces	0.25	5.45	1.53
Sulphuric oxide, SO_3	0.23	....	.....	.....	.....
Phosphoric oxide, P_2O_5	.....	.....	.....	.....	0.09
Organic matter	.....	traces	.....	.....	traces
Water, H_2O	1.98	traces	2.25	4.71	1.40
	99.99	99.34	98.62	98.58	97.08

In the absence of palæontological evidence, it is impossible to determine to which part of the Cretaceous series these beds in Blue Earth county should be referred; but there can be little doubt that they belong somewhere in this age. Scanty exposures of Cretaceous strata are found in many parts of the western two thirds of Minnesota, enclosing sometimes marine fossils, sometimes impressions of leaves, and at a few places thin layers of lignite.

Before the Cretaceous age, during which western Minnesota and the region of the upper Missouri were depressed and covered by the sea, deep channels had been cut by rivers in the Lower Magnesian strata of this county; and the slopes and course of drainage seem then to have been partly like those of the present day. At least we find where the Minnesota river now flows a remarkably water-worn and deeply excavated valley, in which these Cretaceous beds of clay and sand were deposited.

Glacial drift. The drift in Blue Earth county has the same characters in its composition and sources of material, manner of formation, diverse deposits, and topography, as are found generally, except in its belts of terminal and medial moraines, throughout a very large area of southern and western Minnesota and upon much of Iowa and Dakota. In describing the surface features of the county, the topography of the drift-sheet, in its gently rolling or undulating and partly quite flat expanse, and the deep, trough-like valleys which intersect it, have been already sufficiently noticed. The thickness of this sheet of glacial drift is principally from 100 to 200 feet, but in the Mankato well it was found to be 290 feet. Its average upon the whole county is probably 150 feet. Before its erosion by rivers, this was a mantle entirely concealing the bed-rocks, which had no exposure in this region.

The formation of the drift, including removal, intermixture and deposition, took place in the last completed period of geological history, and is found to have been accomplished by the agency of a vast ice-sheet that

rested upon the land and moved slowly forward because of the pressure of its own weight, covering the northern half of North America, as now the Antarctic continent and the interior of Greenland are buried beneath ice thousands of feet deep. In Blue Earth county and generally through the greater part of Minnesota, the material of the drift is principally the unmodified deposit of the ice-sheet, composed of clay, sand and boulders, mixed indiscriminately in an unstratified mass. Very finely pulverized rock, forming a stiff, compact, unctuous clay, is its principal ingredient, whether at great depths or at the surface. This formation is denominated till, boulder-clay, or hardpan. Layers of stratified gravel and sand are enclosed in this deposit, and are the source of the sudden inflow and rise of water frequently found in digging wells.

In this county and upon the western two-thirds of this state, the till has a dark bluish color, except in its upper portion, which is yellowish to a depth that varies from five to fifty feet, but is most commonly between fifteen and thirty feet. This difference in color is due to the influence of air and water upon the iron contained in this deposit, changing it in the upper part of the till from protoxide combinations to hydrous sesquioxide. Another important difference in the till is that its upper portion is commonly softer and easily dug, while below there is a sudden change to a hard and compact deposit, which must be picked and is far more expensive in excavating. There is frequently a thin layer of sand or gravel between these kinds of till, which have their division line at a depth that varies from five to thirty or very rarely forty feet. Owing to the more compact and impervious character of the lower till, the change to a yellow color is usually limited to the upper till. The probable cause of this difference in hardness was the pressure of the vast weight of the ice-sheet upon the lower and older till, while the upper till was contained in the ice and dropped loosely at its melting.

Again, in numerous places the upper till as here described is directly underlain by a softer till, moist and sticky, and dark bluish in color. This is usually of considerable thickness, or between twenty and fifty feet. It often encloses or is underlain by beds of water-bearing sand; but occasionally it has been penetrated and is found to lie directly upon a bed of very compact till, such as usually comes next below the upper till. In some

cases this soft and moist deposit is evidently stratified clay, free from gravel or only holding here and there a stone, and all varieties appear to be found between this and an unstratified and very pebbly till; as indeed it may be that the latter in different localities shows all gradations from its occasionally very soft character, where a shovel can be easily thrust into it to the depth of a foot or more, to the hardest deposits of the lower till in which a pick can be driven only an inch or two at one blow.

The few beds found in this district which contain shells or trees that flourished in interglacial epochs, lie beneath two distinct beds of till, the lower sometimes showing its usual hard and compact character, but elsewhere being even softer than the upper till.

Excepting the division into beds as before described, the till is an entirely unstratified deposit. There has been no assortment of its materials by water, and the coarsest and finest are mingled confusedly in the same mass. Often a thickness of fifty feet or more exhibits no evidence of stratification.

The motion of the ice-sheet upon this part of the state was from northwest to southeast, as is shown by the direction in which the boulders of the drift in this region have been carried, and by the courses of the glacial striæ, or the scratches and grooves worn on the surface of the bed-rock by stones and boulders carried along in the ice. Small rock fragments, varying in size up to the dimension of six inches, are usually numerous and scattered through all parts of the till; they are, however, seldom abundant, and are sometimes so few that in well-boring none might be encountered. Boulders of large size are less frequent, and often a well or even a railroad cut in till fails to display any of greater dimension than two or three feet. Again, several may be found of various sizes up to five or perhaps seven or eight feet. They appear to be usually more numerous on the surface of the till than below. The number of boulders over one foot in size to be found generally upon the surface of moderately undulating tracts of till is estimated to vary from one or two to ten on an acre; but often, and especially on smooth or flat areas, they are more scarce, so that perhaps a dozen could not be gathered on a square mile.

The very smooth, and in many portions flat, surface of the southern two-thirds of Blue Earth county, and of the township of Mankato east from

the top of the river bluff, indicates the extent of a lake which covered this area during the departure of the ice-sheet. In its recession from south to north the ice became a barrier here, as with lake Agassiz* in the Red river valley, preventing free drainage northward, and forming a lake which found its outlet southward in Iowa to the East fork of the Des Moines river, until the ice-sheet was melted upon the region covered by the Minnesota river from Mankato to its mouth. Besides its smooth or flat contour, the till upon the area occupied by this lake is distinguished by slight differences of its material from that of the more undulating districts surrounding it, in having a somewhat scantier intermixture of boulders and gravel, and occasionally in its imperfect stratification. Yet even where it shows distinct lamination, it usually is more like till than like ordinary modified drift, and contains stones and gravel through its entire mass. Rarely may be seen small areas of true laminated clay destitute of gravel. In the report of Faribault county, the outlet, boundaries, area and depth of this lake are treated of more fully.

Near Mankato Junction on the Winona & St. Peter division of the Chicago & Northwestern railway, in section 32, Lime, a cut eighty feet deep (figures 27 and 28) is made in till at the edge of the valley-bluff. The upper forty feet here is yellowish, and the lower forty feet dark bluish. Their line of contact forms a narrow shelf or bench in the cut, six to eight feet wide, apparently due to the greater hardness of the lower till; but their outlines and position make it probable that here their differences both in color and hardness have resulted from weathering. At the southeast end of this cut the yellow till for an extent of two or three rods and a hight of thirty feet is intersected by many nearly vertical banded veins which form an intricate network (figure 29, representing a space ten feet square) upon the steeply sloping face of the excavation. These veins or seams (figure 30) are two or three inches wide, and consist of films of ferric oxide, parted by laminæ of clay, often including near the middle a white or gray calcareous band from an eighth to a third of an inch wide. They appear to be veins of segregation, of somewhat similar origin with the tubular irony concretions which are often met in stratified clay and sand, and more rarely in till. Nowhere else have such vertical veins been found during all my exploration of the glacial drift.

FIG. 27.

FIG. 28.

FIG. 29.

FIG. 30.

ILLUSTRATIONS OF THE GLACIAL DRIFT, SEC. 32, LIME.

Wells in Blue Earth county.

The material and general character of the drift are illustrated by the following records of wells, including examples in most of the townships of this county. For the better exhibition of the succession of glacial deposits, this list is principally selected from the deeper wells of the county. Commonly an ample supply of excellent water, hard because of the presence of dissolved carbonate of lime, but not alkaline, is obtained from fifteen to forty feet below the sur-

*Compare the eighth, tenth and eleventh annual reports.

face, seeping into the well from the lower part of the yellow till, or furnished by springs from thin seams of sand or gravel next below this or within fifteen or twenty feet in the blue till.

Jamestown. Volk & Co.; Volksville, on the shore of Lake Washington, sec. 20: well, 120 feet deep; yellow till, 25 feet; blue till, 30; gravel and yellow sand, 15; ash-colored fetid clay, stratified, 10; sand, 40; no water. Another well, twenty rods from this, is 59 feet deep, being yellow till, 25; blue till, 33; a dark, cemented gravel, mainly composed of waterworn pebbles up to four inches in diameter, 6 inches; and common gravel, 6 inches, with water rising from it four feet.

William H. Rapley; sec. 30: well, 100 feet deep; yellow till, 45 feet, containing veins of gravel from six inches to two feet wide and from four to twelve inches thick; yellow sand, 55 feet; no water.

Le Ray. At Eagle Lake the wells are 16 to 25 feet deep, the deeper going through the yellow till and far enough into the blue till for a reservoir.

Mr. A. W. Redner, of Eagle Lake, a well-maker, states from an experience of about fifty wells in this and adjoining townships, that the yellow till is usually more filled with rock-fragments than the blue till, and is harder to bore or to dig with a spade. The blue till is more sticky. Lignite is frequently found, in pieces up to four inches long, mostly shaly and only half an inch or less in thickness.

Charles & William Macbeth; sec. 20: well, 55 feet deep; yellow till, 20; blue till, 30; quicksand, 1 foot; gravel, 1 foot; blue clay, containing small gasteropod shells, 3 feet.

McPherson. Charles Dittman; S. W. ¼, sec. 5, one mile north of Winnebago Agency (Hilton): well, 75 feet deep; yellow till, 15; at its base a gravel vein, nearly round and about a foot in diameter, was found running across the well; blue till, 55; quicksand, 5 feet and extending below; a small amount of water came in the gravel at fifteen feet, but this was lost in the quicksand at the bottom.

Mankato. Michael Rienbold; sec. 30: well, 30 feet; soil, 2; yellow till, all below; water seeps, being six feet deep in dry seasons.

Mrs. Mary Stuck; also sec. 30: well, 80 feet; yellow till, about 35; sand, 2 feet; blue till, softer than the yellow, 43; water rose forty feet from sand at the bottom.

Decoria. Henry Lortz; sec. 20: well, 33; yellow till, 14; sand, 1½ feet; yellow till again, 17; water rose three feet from sand at the bottom.

Adam Lortz; sec. 21: well, 90; yellow till, about 20; blue till, about 25; light-colored sticky clay, 10 feet; with probably stratified sand and gravel below. This well has only surface water; none in a dry season.

Rapidan. Fred Griffith; sec. 22: well, 24 feet; soil, 2; yellow till, spaded, 15; blue till, harder, but yet spaded, 7 feet; water seeps at the top of the blue till.

Lyra. Graham House; Good Thunder: well, 48 feet; soil, 2; yellow till, 16; soft blue till, 26; gravel and sand, 4 feet, with water issuing in this stratum but not rising above it.

R. L. Potter; sec. 33: well, 70; soil, 2; yellow till, 15; blue till, 53; water rises from gravel at the bottom to a hight six feet below the surface. This is the deepest well of its vicinity; it is at the general level of the country, about fifty feet above the Maple river. Nine rods farther east, a well 14 feet deep found a good supply of water, rising four feet from the bottom.

Sterling. W. Wells; sec. 4: well, 16½ feet deep, being all yellow till; water rose ten feet in four hours from sandy streaks at the bottom.

Garden City. At Lake Crystal, in the north edge of this township, the common wells are 15 to 30 feet deep. The well for the railroad and elevator here has a depth of 110 feet, of which the last 50 feet were bored. Its section is soil, 2 feet; yellow till, spaded, 15; softer and moister blue till, becoming more gravelly in the last 6 or 8 feet, 90; gravel, 3 feet; water rose from the bottom only twenty-five feet, but the well, when not pumped from, becomes filled with surface water.

Vernon Center. C. C. Washburn; N. W. ¼ sec. 26, close east of Edgewood station: well, 22 feet; soil, 2; yellow till, spaded, 20 feet; water seeps. At his barn, twelve rods to the south, is another well, 34 feet deep, having soil, 2 feet; yellow till, 18; harder blue till, 10; sand and gravel, 4 feet, from which water rose twenty-four feet in a half day, and stands permanently at this hight. The wells of this region average 20 to 30, and are occasionally 40 to 50 feet in depth. Lignite, in fragments up to four inches long, is found sparingly in the till in nearly all these wells.

Pleasant Mound. F. O. Marks; S. E. ¼, sec. 25: well, 55 feet; soil, 2; gravel, 6; light-gray "hardpan," very hard, 18; blue till, soft and moist, 29; water rose thirty-five feet in a few hours from a dark mud at the bottom.

William Robinson; sec. 26: well, 64; soil, 2; yellow till, spaded, 18; sand and gravel, 1 foot; soft and moist blue till, 43; with quicksand at the bottom, from which water rose thirty feet in six hours.

Ceresco. L. A. Pratt; sec. 24: well, 48; soil, 3; yellow till, spaded, 15; softer and moister blue till, 28; sand and gravel, 2 feet, reaching deeper; water rose four feet from this sand. Small fragments of lignite occur frequently in the wells of this region.

Lincoln. W. G. Bundy; sec. 30: well, 30 feet; soil, 2; yellow till, spaded, 24; harder blue till, 4 feet, and reaching deeper; water comes in sandy and gravelly veins in this blue till, becoming four or five feet deep.

Butternut Valley. Thomas Wilson; sec. 28: well, 58 feet; soil, 3; yellow till, spaded, 15; blue till, soft and moist for the first five feet, then mostly very hard and compact, requiring to be picked, in all, 40 feet, containing a piece of lignite, nearly a cubic foot in size, at a depth of about thirty feet from the surface; no sand nor gravel, and no good supply of water; this well has therefore been filled up.

Martin Osten; sec. 21: well, 28 feet; soil, 2; yellow and blue till, 26; with gravel and sand at the bottom, from which water rose to six feet below the surface.

Cambria. David T. Davis; sec. 26: well, 40; soil, 2; yellow till, spaded, 18 feet, containing gravelly streaks in its lower part, with a little water; much harder blue till, picked, 20; enclosing a vein of gravel and sand at the bottom, from which water rose two feet.

William E. Jenkins; sec. 34: well, 24 feet; soil, 2; yellow till, 18; harder blue till, 4 feet and extending lower; water seeps. Several small pieces of lignite were found in each of these wells.

Modified drift. In addition to the beds of modified drift enclosed in the till or lying below it, other accumulations of this kind of drift, derived directly from the ice-sheet but deposited by water, occur on the surface of areas which are mainly till. They consist of interstratified gravel and sand in knolls or mounds that rise ten to twenty feet, and rarely fifty to seventy-five feet, above the general level. These are seldom very numerous in western Minnesota, and are rarely extended in ridges or in any notable series. Their origin, however, was probably similar to that of the gravel ridges or kames which often form long series in other drift regions, being the deposits formed between walls of ice by glacial rivers that were poured down from the surface of the melting ice-fields. The only notable accumulations of this class in Blue Earth county are the group of hillocks before described in section 25, Pleasant Mound, and occasional knolls of fine gravel and sand, ten to fifteen feet in hight, in Butternut Valley and Cambria townships.

The valley of the Minnesota river at the north side of the county has been filled with modified drift to a depth of about one hundred and fifty feet, but it has since been nearly all excavated and carried away by the river.

Modified drift.]

At and opposite New Ulm, and four to eight miles farther down the valley, in Courtland, which adjoins Cambria, are conspicuous terraces of sand and gravel belonging to this formation, having hights from 100 to 150 feet above the river. Opposite to the southeast end of the Courtland terrace, a remnant of the same deposit lies in section 22 and the N. E. ¼ of section 21, Cambria, between the Minnesota river and the lower part of Morgan creek, having a hight of 100 feet or more and a length of about a mile.

Between Judson and Mankato, close southeast from the unnamed waterfall formed by the Jordan sandstone in section 12, Judson, the road rises about 75 feet higher, to a terrace composed mainly at its surface of coarse gravel and sand, irregularly and obliquely interstratified, upon which the road runs one and one-fourth miles southeast to the wind-mill in the N. E. ¼ of section 18, South Bend, where it is called the "Wind-mill bluff." This terrace of modified drift is two and a half miles long, reaching from the N. W. ¼ of section 12, Judson, to the S. E. ¼ of section 17, South Bend; its greatest width is about a third of a mile; its hight is estimated at from 170 to 150 feet above the river, declining toward the southeast, the bluffs of till at its southwest side being 30 to 50 feet higher, or 200 feet above the river.

In the farther descent of the valley, no other remains of this great deposit of stratified drift are found in the next ten miles; but, beginning again one mile beyond the north line of Blue Earth county, they are found thence commonly on one or the other side of the valley through its lower sixty miles, from Kasota and Saint Peter to its mouth. The depth of this valley drift, consisting of horizontally stratified gravel and sand, sometimes with thick beds of clay, is found by wells to be from 50 to 100 feet. This is at the side of the valley, in which this formation appears to have been a continuous flood-plain, gradually raised by the deposition of sediment, till its thickness along the middle of the valley, from which it has now been eroded, was from 75 to 150 or 175 feet, having a slope down-stream of about two feet per mile. The floods which brought this deposit and flowed over its broad plain were supplied from glacial melting.

The comparatively thin deposits of similar stratified gravel and sand, which cover the terraces of the Shakopee limestone and Jordan sandstone within the Minnesota valley, in this county and below, and the alluvium of the bottomlands, which are composed of fine silt, sand and occasional beds of gravel, have been worn and assorted by water nearly like the modified drift; but their origin seems attributable to the ordinary action of the river in the processes of excavation and sedimentation, and may be accounted for without reference to glacial conditions.

MATERIAL RESOURCES.

The principal resources of Blue Earth county are the products of its invariably fertile soil, and the water-powers afforded by many of its streams, which, by using their lakes for reservoirs, may be made nearly uniform in flow throughout the year. The valuable areas of timber and the prairies of natural grassland in this county both possess rich, deep, and well drained soil, bountiful and never-failing in its productiveness. Besides the agricultural capabilities of Blue Earth county, which have been before noticed, we have to enumerate here its water-powers, its quarries of building stone, the manufacture of lime, hydraulic cement, bricks, drain tiles and pottery, and artesian wells and fountains.

Water-powers in Blue Earth county.

The following water-powers are utilized in this county, all being employed for the manufacture of flour, excepting two saw-mills, of which one is situated on the Le Sueur river, in the southeast part of Mankato township, and the other in Le Ray on the outlet of Eagle lake.

Blue Earth river. Champion mills; V. H. Thompson; in the north part of sec. 16, Shelby; fall or head, seven feet; three run of stone.

Standard mills; Berry & Crow; Vernon Center, west of road, and north of river; head, seven feet; three run of stone.

Cable mills; Turner & Redfern; at middle of east half of sec. 18, Lyra; head, about seven feet.

Union mill; N. E. ¼ of sec. 31, Rapidan; head, about six feet; grist-mill.

Rapidan mills; Rapidan Mill Co.; at Rapidan Rapids; head, ten feet; mostly a custom mill.

Watonwan river. C. F. Butterfield's mill; in S. W. ¼ of sec. 32, Garden City; head, eight feet, as now located; owner expects to remove mill to a point about an eighth of a mile northeast, there to have a head of nineteen feet, four of it being gained by raising the present dam.

Watonwan mills; F. T. Enfield; upper mill in Garden City; head, seven feet; three run of stone.

Northwestern mills; Andrew Friend; lower mill at Garden City; head, seven feet; three run of stone; custom (exchange) and merchant mill.

Moore & Richardson's mill (formerly Folsom's); in S. E. ¼ of sec. 23, one mile below Garden City; head, about nine feet; two run of stone.

Maple river. Sterling mill; Mrs. M. Furman; just below mouth of Jackson creek, in the S. E. ¼ of sec. 9, Sterling; head, six feet; obtains water for dry season by raising and drawing four feet from lake Jackson at the west side of this township, and the same from Rice lake in Delavan, Faribault county.

Good Thunder mills; Palmer & Miller; two-thirds of a mile southeast from Good Thunder, beside the Mankato branch of the Southern Minnesota railroad; head, seven feet.

H. B. Doty's mill; in (or near) the N. E. ¼ of sec. 3, Lyra, one and a half miles north of Good Thunder; head, ten feet.

Maple River mills; George Gerlich; in the southeast part of Rapidan, four miles north of Good Thunder; head, twelve feet. All these are small custom flouring mills.

Outlet of Eagle lake and lake Madison. On this tributary of the Le Sueur river mills are owned by

Cate & Zimmerman; N. W. ¼ of sec. 20, Le Ray; one and a half miles southeast from Eagle lake; flour and grist mill; head, twenty-one feet.

Ellison & Ford; one mile south of the last, in sec. 29, Le Ray; saw-mill; head, fourteen feet.

Le Sueur river. Harvey & Bennett; Tivoli post-office, in sec. 25, southeast part of Mankato township; saw-mill; head, about nine feet.

Red Jacket mills*; Hillyer & Bingham; S. W. ¼ of sec. 26, Mankato, three and a half miles southwest from the city; head, twelve feet; canal, a third of a mile long; four run of stone; wholly a merchant mill.

Quarried stone. The St. Lawrence limestone in Judson has been worked at several places. On land of Mrs. G. W. Wolf it is quarried both at the south and north sides of a small lake which is close northeast of her house (Judson post-office); and also about sixty rods farther southeast. Work was begun here fifteen years ago; and sales have averaged about a hundred cords yearly. Only rough stone of small dimension is obtained, bringing from $2 to $4 per cord. At C. G. Swanson's quarry, a half mile southeast from the foregoing, the excavation is twenty rods long and exposes a vertical thickness of four or five feet. The sales at present are about twenty-five cords annually, at $2.50 to $3 per cord. John Goodwin's quarry, about a half mile farther southeast, has not been worked during the last five years.

The Shakopee limestone is much quarried in Blue Earth county. It

*Burned since this report was written.

is strong and durable, of attractive buff color, easily wrought to any desired form, and usually thickly bedded, supplying the largest sizes of dimension stone.* Its quarries here noted lie within the Minnesota valley in South Bend, Mankato and Lime townships, and in Belgrade, opposite Mankato; on the Blue Earth river, near the west part of the city of Mankato, and in the N. W. ¼ of section 27, South Bend; on the Watonwan river close below Garden City; within the valley of the Le Sueur river in sections 2 and 11, Rapidan; along the last mile of Maple river; and on the Big Cobb river in the west part of Decoria. The character of the formation at these localities has been already stated, and the ownership, situation, and extent of business of its quarries remain to be briefly mentioned.

At South Bend, beside the railroad, this limestone has been considerably quarried by David P. Davis, but little has been done here within the last few years.

In the north part of Mankato quarries are owned by J. R. Beatty, George Maxfield, the Chicago & Northwestern railway company, Adam Jefferson, and others. J. R. Beatty's east quarry reaches about thirty rods west from the north end of Front street. It has been operated about fifteen years, formerly supplying some eight hundred cords yearly at $3 per cord; but was not worked in 1879 and 1880. At present (1883) it supplies a large amount of stone both for building and for quicklime. In the bottom of the quarry the stone is blue.

George Maxfield's quarry, extending thence a quarter of a mile west, was leased from 1878 to 1880 to O. R. Mather, whose annual sales amounted to about $8000. This quarry supplied the masonry of the bridge at Shakopee, and the trimmings of the high school building at Le Mars, Iowa. The section here is given on page 429, the bluff of these quarries reaching from the top of the formation as there described to No. 9. Some portions of No. 3 are fossiliferous. In No. 4, a layer three feet thick, twelve to fifteen feet above No. 5, is reddish, having about the same tint as in the Kasota quarries, and is a good stone for cutting. Next above this is a thickness of eight feet used for common masonry. Another layer in No. 4, which is somewhat used for cut-stone, lies about six feet above No. 5; it is light straw-colored, and is finely laminated with curving concretionary films of ferric oxide. No. 6, called the best cutting stone, has a brownish buff color.

Adjoining the last and continuing northwesterly is another quarry owned by J. R. Beatty, from which the sales up to 1880 were about $1000 yearly. A third of a mile farther north, in the S. W. ¼ of section 6, this bluff has been quarried by Stephen Lamm & Co., who, jointly with Sullivan and Duffee, quarrying in Belgrade, supplied the stone for the Mankato bridge. These quarries, or others recently opened near them, are at present extensively worked by the Chicago & Northwestern railway company†, and for supplying the stone of the arched railroad bridge built in 1882 and 1883 at Minneapolis.

Half a mile farther north, in the N. W. ¼ of section 6, Adam Jefferson has quarried since 1877, selling about $1000 worth of stone yearly, at $3.50 per cord, and from fifteen to fifty cents per foot for cut stone, as window caps and sills. He supplied the masonry of the Le Sueur bridge. This quarry and that of Lamm & Co. expose a vertical thickness of fifteen to twenty feet, being in No. 4 of Prof. Winchell's section.

About a quarter of a mile farther north, yet in Mankato, a small quarry has been worked by Nathan Brooks.

In Lime township J. R. Beatty & Co. quarry extensively at the south side of a little creek in the S. W. ¼ of section 20. The working extends about fifteen rods on the face of a bluff which

*Consult the chapter on building stones, p. 166.

†At this quarry the workmen have the following designations for the different parts of the quarry, adopted for their own convenience. They are in descending order. 1. White ledge (very fine-grained stone). 2. Red ledge (harder and pinkish). 3. Gray ledge (coarse-grained). 4. Soft ledge (crumbled by freezing). 5. Bridge stone (coarse).

exposes twenty to twenty-five feet of this limestone, vertically, in beds from one to three or four feet thick. Quarrying was begun here in 1878, and in 1879 furnished the stone used for the Belle Plaine bridge, the sales of that year being $2500. Within a third of a mile southwestward, Joseph Kunz has quarried considerably at several places on his farm in the S. E. ¼ of section 19.

Valuable quarries of this limestone are worked upon the west bluff of the Minnesota river in Belgrade, Nicollet county, opposite to Mankato.

The St. Paul & Sioux City railroad company have quarried upon both sides of the Blue Earth river near their railroad bridge. The stone for the new bridge crossing this river in section 27, South Bend, was being quarried in 1880, about a sixth of a mile above it, from the Shakopee limestone which forms the upper part of the bluff north of the river.

The quarrying mentioned beside the Watonwan river, close below Garden City, on land of the S. M. Folsom estate, has been of small amount, perhaps supplying in all fifty cords of stone.

In the valley of the Le Sueur river, the fallen blocks of Shakopee limestone before spoken of on land of O. Halberg, in the east half of section 2, Rapidan, have been somewhat used for masonry; but this rock was not seen in place in the bluff above, which rises to a hight of seventy-five feet. Andrew Algren quarries this limestone slightly at its outcrop on his farm, less than a mile above the last, in the N. E. ¼ of section 11, Rapidan, getting out ten to twenty cords yearly.

Quarries on the Maple river within a mile above its mouth, in sections 12 and 13, Rapidan, are owned as follows: by Columbus Ballard, at the west side of the river, in the N. E. ¼ of the S. W. ¼ of section 12, leased to John C. Roland through several years past, considerably used for bridges, house-building, &c.; by Swan Larson, west of the river, in the S. W. ¼ of the S. W. ¼ of section 12, selling ten to twenty cords yearly at $3 per cord; by A. C. Wood, east of the river, in the S. E. ¼ of the S.W. ¼ of section 12, yielding excellent stone and considerably quarried; and by P. H. Kelly, in the N. ½ of the N. W. ¼ of section 13, also good, but not recently worked. The west pier of the bridge at Garden City was from Ballard's, and the east pier from Kelly's quarry.

In Decoria the Shakopee limestone on the lower part of the Big Cobb river has been quarried since 1875 by Matthew Ryan, in section 18, selling some seventy-five cords yearly, at $3 per cord; and since 1877 by A. W. White and Samuel Curtis, in section 19, selling annually ten or twenty cords. These quarries only supply the demands of their vicinity, and are scantily worked because they lack a sufficient market; but the stone here and on Maple river seems to be equal in quality to that of Mankato.

Lime. The St. Lawrence limestone in Judson appears never to have been used for lime-burning. From the Shakopee limestone on the Maple river lime was manufactured about fifteen years ago, but not since, because its cheapness at the Mankato kilns prevents competition.

At Mankato lime is burned by J. R. Beatty and O. R. Mather, from the layer No. 3 of Prof. Winchell's section of the Shakopee formation here. This buff dolomite produces a dark lime which slacks to a brown or cream color. It is magnesian, with a little admixture of sand, and is burned more easily, slacks with less heat, and sets more slowly, than pure lime. It is preferred by masons for brick and stone work, and for plastering except the finishing coat.

J. R. Beatty's kiln, at the west side of the north end of Front street, has been in operation ten years, averaging 7,000 barrels of lime yearly. It is a continual burner, with annual capacity of 12,000 barrels. O. R. Mather since 1878 has leased George Maxfield's kiln at the east side of the street, opposite to the foregoing, and burns about 6,000 barrels per year. This lime varies in price from fifty to seventy-five cents per barrel of about 225 pounds.

One and a third miles northwest from these kilns, in the N. W. ¼ of section 6, Mankato,

Hydraulic cement.]

Adam Jefferson has burned two thousand to three thousand barrels of lime yearly since 1868.

The upper five to eight feet of the quarry worked by J. R. Beatty & Co., in Lime township, are excellent for lime, of which they here burned 2,000 barrels yearly in 1878 and 1879. Joseph Kunz, in the adjoining section 19, has also burned lime.

Hydraulic cement is manufactured by the Standard Cement company, on the east bank of the Blue Earth river about a mile southwest from the west part of the city of Mankato. The discovery of the hydraulic quality of the Shakopee limestone at this place is to be accredited to Mr. J. R. Beatty. The cement is made from the regular layers of the Shakopee, the whole exposed thickness of the strata, amounting to about twenty-two feet, being involved in the process. The rock varies somewhat from top to bottom, being too siliceous in one part and too calcareous in another, but when mingled in the process of manufacture makes a good hydraulic cement. Samples of the strata, selected for their excellence, have been analyzed by Mr. C. F. Sidener under the direction of Prof. Dodge, with the following result:*

No. 144. The powdered rock was digested in hydrochloric acid, whereby the greater part of it was dissolved with effervescence due to the escape of carbonic acid gas. The composition of the soluble and the insoluble portions is as follows:

Soluble in hydrochloric acid.

Calcium carbonate, $CaO\ CO_2$	40.00
Magnesium carbonate, $MgO\ CO_2$	31.50
Ferric oxide, Fe_2O_3	2.73
Silica, SiO_2	traces
Alumina, Al_2O_3	0.85
Potassa, K_2O	0.22
Soda, Na_2O	0.54
	75.84

Insoluble in hydrochloric acid.

Silica	16.00
Alumina	5.00
Potassa	traces
Soda	traces
	21.00
Water	0.43
	97.27

The soluble portion is seen to be mainly carbonate of lime and carbonate of magnesia, with some oxide of iron, while the insoluble portion is silicate of alumina.

The chemical characters of the manufactured cement have been determined by Mr. Sidener as follows:*

No. 145. This material was found to effervesce very little with hydrochloric acid. It was accordingly analyzed as a silicate, by fusion in the usual manner. The result of the analysis is as follows:

*Twelfth annual report.

Lime, CaO	38.53
Magnesia, MgO	22.73
Ferric oxide, Fe_2O_3	4.71
Silica, SiO_2	16.24
Alumina, Al_2O_3	5.35
Potassa, K_2O	1.81
Soda, Na_2O	0.57
Water, H_2O	0.51
Carbonic acid, CO_2	9.26
	99.71

This company, beginning operations here in 1882 and 1883, have erected extensive buildings for carrying on the business, using the same rock in their construction. The Shakopee formation at this place has a different grain and texture from the strata seen at the quarries in the north part of Mankato and elsewhere.*

It seems to have more nearly the characters of the lower part of the Shakopee limestone quarried by J. R. Beatty & Co. in section 20, Lime, which on analysis showed a similar composition, being reported by Prof. Dodge as follows:†

No. 74. Rock a siliceous limestone. Digested with hydrochloric acid, a residue was left, amounting to 19.67 per cent. The dissolved portion was therefore 80.33 per cent.

Analysis of portion dissolved by hydrochloric acid:—

SiO_2	.27 per cent., being	.21 per cent. of whole rock.	
Al_2O_3	.15 " " "	.11 " " " " "	
Fe_2O_3	3.03 " " "	2.43 " " " " "	
CaO CO_2	55.62 " " "	44.68 " " " " "	
MgO CO_2	39.13 " " "	31.59 " " " " "	
	98.20	79.02	

Analysis of portion not dissolved by hydrochloric acid:—

SiO_2	78.27 per cent., being	15.29 per cent. of whole rock.	
Al_2O_3	18.33 " " "	3.61 " " " " "	
CaO	.48 " " "	.09 " " " " "	
MgO	.23 " " "	.04 " " " " "	
Alkalies	traces.		
Organic matter	traces.		
	97.31	19.03	

A determination of water in the dried powder gave 4 per cent. (of whole rock.)

This is therefore a magnesian limestone, containing about 15 per cent. of silica, and but a moderate quantity of oxide of iron. It would appear likely to make a good hydraulic lime. No. 71 might also serve that use.

No. 71 is described by Prof. Winchell as "light blue calciferous sandrock, from the lower part of the quarry of Maxfield and Mather, Mankato, showing non-hydrated (un-oxidized) natural condition of the deeper beds of the Shakopee formation." Prof. Dodge says of this rock:‡

Ten grammes of the powdered and dried mineral were digested with hydrochloric acid; a residue was left which weighed 1.552 gms., making 15.52 per cent. of the rock; the portion dissolved was therefore 84.48 per cent.

*A bed of clay or shale underlying the Shakopee limestone at the Standard Cement company's quarry, and apparently associated with the qualities in the limestone which adapt it for the manufacture of hydraulic cement, is described on page 454.

†Tenth annual report, p. 204.

‡Same, p. 203.

Analysis of portion dissolved by hydrochloric acid:—

Fe_2O_3 with small amount of Al_2O_3 and SiO_2	3.14 per cent.,	being 2.65	per cent. of whole rock.
CaO CO_2	55.47 " "	" 46.86	" " " " "
MgO CO_2	39.73 " "	" 33.56	" " " " "
	98.34	83.07	

Analysis of portion left undissolved by hydrochloric acid:—

SiO_2	77.90 per cent.,	being 12.10	per cent. of whole rock.
Al_2O_3	19.24 " "	" 2.99	" " " " "
CaO	.34 " "	" .05	" " " " "
MgO	.12 " "	" .02	" " " " "
Alkalies	traces.		
Organic matter	traces.		
	97.60	15.16	

It appears, therefore, that the rock is a magnesian limestone, with about 12 per cent. of silica and somewhat over 2½ per cent. of oxide of iron.

Bricks. The principal brick-making in this county is at Mankato.

The Mankato Brick company, O. R. Mather, superintendent, has three yards, two of which, making cream-colored bricks, are situated in the north part of the city, about fifty rods southwest from the lime-kilns, while the third, making red bricks, is a mile distant to the southwest. They all are on the bottomland, and the material used is the recent alluvium of the Minnesota river, the excavations reaching from the level of low water to fifteen feet above it. No sand is needed for tempering at these or the following yards. The difference in color of these bricks seems to be due to the mode of burning. With a rapid, hot fire, they take a light buff or cream color through the whole kiln; but when more slowly burnt they are red, except near the fire, where they become brownish or whitish gray. This business was begun ten years ago, and the annual product has averaged about 4,000,000. In 1880 it was 6,000,000, about two-thirds being cream-colored and one-third red. The bricks are sold at $5 to $7 per thousand, loaded upon the cars. Many of them go to distant points, as Saint Paul, Minneapolis, and Duluth, and to southwestern Minnesota and northern Iowa. About a sixth of a mile southwest from the third of the foregoing yards, in the west part of Mankato, F. Polchow & Co. have made red bricks eight years, averaging 4,000,000 yearly, and selling at about $6 per M. The material used is the same fine alluvial silt of the river. All these bricks are of excellent and durable quality.

In 1879 Willimes & Grothe began making bricks about one and one-fourth miles north of Mankato, being at the south side of a creek close southwest of Jefferson's quarry. They also use alluvium, producing red bricks excepting near the fire, where they are light gray. About 150,000 were made in 1879, and 3,000,000 in 1880, bringing $5 to $5.50 per M.

Red bricks have also been made since 1878, by Gekeler brothers, in the N. W. ¼ of section 8, McPherson, using the alluvium of the Le Sueur river. Their annual product is about 50,000, selling at $5 per M.

Brick-making was formerly done, but is discontinued, at five places in the west part of the county, as follows: by O. R. Mather, from 1867 to 1871, on the southeast side of Willow creek, in the S. W. ¼ of section 6, Shelby, producing red bricks of fair quality; also by Mr. Mather, during the next two years, in the southwest edge of the town of Lake Crystal; in 1869, south of the Garden City fair-ground, on the north bank of the Watonwan river, red bricks, cracked by particles of limestone contained in the sand which was employed for tempering, while the clay used is free from gravel and is said to have been tested in the Mankato pottery and found suitable for making stone-ware; in the N. W. ¼ of section 8, Shelby, on the east side of the Blue Earth river, about eight years ago; and, at nearly the same date, in the S. W. ¼ of section 32, Ceresco, west of Perch creek.

Fire-bricks. Mr. David P. Davis states that the Cretaceous clay in the lower part of his quarry at South Bend has been tested, and found to be

of superior quality, for the manufacture of fire-bricks. From the pottery clay and sand of this age close east of the railroad bridge over the LeSueur river, fire-bricks are successfully made by Andrew Gapter, whose price for them is $40 per thousand at wholesale, and ten cents apiece in small lots.

Drain-tiles. S. F. Alberger, of Mankato, has recently begun the manufacture of drain-tiles. The clay used is obtained in the bluffs of the Le Sueur river and its tributary from the east known as Chalk run, in the S. W. ¼ of section 35, Mankato, being from No. 2 of the Cretaceous section recorded on page 435. The tiles made are firm and compact, and of a light red or pinkish color, varying to yellowish.

Pottery. Andrew Gapter has made pottery in the northeast part of Mankato since 1877; obtaining the clay used during the first two years from the bluffs of the Cottonwood river in section 3, Sigel, near New Ulm; but since then getting all the kinds of clay and sand required from the Cretaceous strata just mentioned on the Le Sueur river. He sells yearly about $3,000 worth of ware, the price being eight to nine cents per gallon. It is strong and durable, having, when not glazed, a reddish brown color.

Artesian wells and fountains. Some notice of the common wells of Blue Earth county, and of the ample quantity and good quality of their supply of water, was given in treating of the glacial drift.

The well at Mankato, 2,204 feet deep, the section of which has been presented on page 423, found no artesian flow of water, and is not used. It was drilled for the city, in the winter of 1874–5, at a cost of $12,000. About half its depth is six inches in diameter; and the portion below, three and five-eighths inches. Water was found in one of the layers of sand in the till at 85 feet. Within the rock it was first found at 540 feet, from which depth it rose to 90 feet below the top of the well. At 1,160 feet the drill fell a little, and from this new source the water rose ten feet higher. At 1,975 feet the drill again dropped, and the water rose ten feet higher still, to 70 feet below the surface. The supply appears, as tested by pumping, to be enough for the city's needs; and as the well is at the top, and near the edge, of the bluff, 200 feet above the greater part of the city, the water may be obtained and the well utilized by tunneling to it at a depth of eighty or ninety feet below its top.

Many flowing or artesian wells, called fountains, probably more than

one hundred in number, have been obtained by boring to slight depths, from 25 to 75 feet, in the till, upon the area drained by the head-streams of Maple river, from Sterling Center fifteen miles southeastward, including Sterling and Mapleton townships in Blue Earth county, and reaching into Faribault county. It may be that this artesian water is continuous a half dozen miles still farther southeast to Wells, where the most remarkable flowing wells, or fountains, in Minnesota have been found. Though the water at Wells is obtained 110 to 120 feet below the surface, it is yet at a greater hight above the sea than in the shallower fountains on the Maple river.

These fountains are mostly bored in the valley of this stream, forty feet below the general level of the adjoining country, or in the similar valleys of its tributaries, which are depressed fifteen to forty feet. Near the Maple river they are commonly about thirty feet deep, being pipe from a half inch to one and a half inches in diameter, and the water rises from them five to ten feet above the surface. The sand and gravel which yield this water are not encountered everywhere upon this area, so that many borings in favorable situations get no artesian flow. It also seems likely that some localities have more than one stratum from which water may rise above the surface. For example, three fountains bored by William Randall in the southwest part of section 14, Sterling, in the valley of a small creek tributary to the Maple river which flows through the north part of this section, are 30, 50, and 60 feet deep, in their order as one follows down the creek. From the first to the third is about a third of a mile, in which distance the creek probably falls fifteen feet, making the difference in hight of the water-bearing sand at these points forty-five feet; suggesting, as the surface of the drift-sheet upon this region is nearly level, that these layers of sand, instead of being parts of any continuous stratum, may be distinct and independent of each other. The section of the lowest fountain here, 60 feet deep, was soil, 2 feet; soft and sticky blue till, 38 feet; sandy clay, thought to be free from gravel, 20 feet; with sand at the bottom from which the water rose in one minute to the surface.

The owners of the four mills on Maple river, and of the Red Jacket mill on the Le Sueur river, having been often hindered by scarcity of water, offered to pay $50 from each mill, if a hundred cubic feet of water per minute should be added to the Maple river by fountains. Well-makers accordingly obtained the right to bore on two farms and six fountains were obtained on each. One of the farms is now owned by E. W. Hicks, living close east of the northwest corner of section 14, Sterling. The largest of the fountains bored here forms a stream two feet wide and six inches deep. The other six fountains are on Mr. Cornell's farm, in the west edge of Mapleton, three miles farther southeast. Together the twelve fountains yield 135 cubic feet of water per minute; for which these mill-owners paid $325. This was done in 1877, and is regarded as a good investment, for this additional flow is constant through the year and enables the mills to work in the driest seasons.

CHAPTER XIV.

THE GEOLOGY OF FARIBAULT COUNTY.

BY WARREN UPHAM.

Situation and area. Faribault county (plate 17) is the central one in the tier of nine counties on the south side of the state, bordering Iowa. The distance from its north line north-northeast to Saint Paul and Minneapolis is about 90 miles; and from its east line to the Mississippi river at La Crosse is 120 miles. This county is a rectangle, its length from east to west being five townships, or thirty miles, and its width from north to south four townships, or twenty-four miles. Its area is 723.72 square miles, or 463,184.53 acres, of which 9,151.21 acres are covered by water. The largest towns and villages are Blue Earth City, Winnebago City, Delavan, Easton, Wells, and Minnesota Lake.

SURFACE FEATURES.

Natural drainage. The whole of Faribault county lies within the basin of the Blue Earth river, which flows northerly through its two western ranges of townships; while the East fork of this river, formed by Jones and Brush creeks in the southeast part of the county, flows west through its southern half and joins the main stream at Blue Earth City. The middle part of the northern third of the county is drained by the head-streams of Maple river, which is tributary to the Le Sueur and through that to the Blue Earth river. Dunbar, the most northeastern township, is drained principally by the Big Cobb river, also reaching the Blue Earth through Le Sueur river. The general slopes of the surface thus descend northward;

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA

FARIBAULT COUNTY.

BY WARREN UPHAM.

Explanation

Modified Drift: Kames

Glacial Drift: Till, flat or undulating; Moraine Till, rolling; Moraine Till, knobby-hilly

Contour Lines are drawn approximately for each 50 feet above the sea.

Julius Bien & Co. lith.

Topography.]

from the southeast part of the county westerly to Blue Earth City; and from its west boundary easterly to the Blue Earth river.

Lakes. Faribault county has frequent lakes, the largest of which is Minnesota lake, two and a quarter miles long from east to west and one to one and a half miles wide, lying in the northwest part of Minnesota Lake township, with its north edge reaching into Blue Earth county. Others deserving mention are Rice lake, in Delavan, three and a half miles long from north to south, and averaging about a half mile in width; Bass lake, north of the last, and only divided from it by a low and narrow ridge; Swan lake, about two-thirds of a mile long, with two or three others of smaller size, forming a group near the center of Barber township; Ozahtanka lake, having an area of about two square miles, in Barber and Emerald; Walnut lake, also covering about two square miles, in the south part of Walnut Lake township, and extending south into Brush Creek and Foster; Goose and Swan lakes, within a mile farther south in Brush Creek; and five lakes, from a half mile to one and one-fourth miles in length, lying in the southwest part of the county, in Jo Daviess and Pilot Grove townships.

Topography. The greater part of this county has a slightly undulating or often nearly flat surface, with slopes of very gentle and commonly imperceptible descent toward the water-courses. The streams have channeled from thirty to one hundred feet into the drift, which forms the surface and everywhere covers the county so deeply that the bed-rocks have no exposure within its limits. The East branch of the Blue Earth river at Clayton, in the north edge of Seely township, flows 30 feet below the general level; at Blue Earth City the valley is 50 feet deep; and northward through Verona and Winnebago City, its depth increases from 50 to 90 or 100 feet. Its bottomland, five to twenty feet above the stream, is mainly from a quarter to a half of a mile wide, bordered by steep bluffs that rise to the almost flat expanse of till upon which Blue Earth City and Winnebago City are built, and which covers the whole county excepting two belts of morainic hills. One of these extends from Kiester, in the southeast corner of the county, northwestward nearly to Delavan; and the other, which lies mostly in Iowa, includes the southern edge of Elmore and Pilot Grove. Many further details respecting the contour are stated in a later part of this chapter, in the description of the drift.

Elevations on the Southern Minnesota division of the Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Dood's switch, near the east line of the county	139.7	1189
Wells	144.4	1153
Junction of the Mankato branch	144.7	1145
Minnesota Lake station, on this branch	153.0	1038
Easton	153.3	1046
Summit, grade	157.1	1077
Delavan	159.2	1057
Depression, grade	159.5	1047

Crossing branch of C., St. P., M. & O. railway	166.1	1095
Winnebago City	166.3	1096
Blue Earth river, water	168.4	1014

The elevations above the sea of the Blue Earth river and its tributaries in Faribault county are approximately as follows: Blue Earth river at the south line of the county and state, 1125 feet; at the mouth of the East fork, in Blue Earth City, 1050; at the north line of the county, 990; Jones creek at the east line of the county, 1200; Walnut lake, 1125; Maple river at the north line of the county, 980; and the Big Cobb river in Dunbar, 1075 to 1100.

Mean elevation of the county. Estimates of the average hight of the townships of Faribault county are as follows: Dunbar, 1120 feet above the sea; Clark, 1170; Foster, 1200; Kiester, 1250; Seely, 1175; Brush Creek, 1125; Walnut Lake, 1125; Minnesota Lake, 1050; Lura, 1040; Barber, 1100; Emerald, 1125; Rome, 1160; Elmore, 1160; Blue Earth City, 1120; Prescott, 1100; Delavan, 1050; Winnebago City, 1080; Verona, 1100; Jo Daviess, 1150; and Pilot Grove, 1180. The mean elevation of the county is thus 1130 feet, very nearly, above the sea. Its highest points, the hills in section 3, Kiester, are about 1400 feet above the sea; and its lowest land, in the valleys of the Blue Earth and Maple rivers, slightly less than 1000.

Soil and timber. The soil of Faribault county has the usual character of the whole area of slightly undulating glacial drift which overspreads the basin of the Minnesota river. It is almost universally the unmodified drift, or till, consisting principally of clay, but enclosing a considerable proportion of sand and gravel and occasional stones and boulders. A thickness of about two feet of this deposit next to the surface has been made dark by decaying vegetation, and is the black soil. On the top of swells, and especially of the morainic hills and ridges, its depth is sometimes only about one foot, but is rarely much less; and in the depressions it is often three or four feet deep. This soil has a sufficient intermixture of sand to make it porous, easily allowing rains to soak into it and moisture to rise through it to the surface in a drought. It is therefore ready for early sowing and planting soon after the snow has melted in spring, and can well endure either very wet or unusually dry seasons. Besides wheat, which was formerly its leading crop, Faribault county is well adapted for raising oats, corn, hay, horses, pork, beef, butter, amber cane, flax, potatoes, and the ordinary vegetables and small fruits of the garden, all of which now receive due attention in the agriculture of this region.

Timber of large and dense growth usually occupies the bottomlands

Timber. Geological structure.]

and bluffs of the Blue Earth river through this county, and of its East fork to a distance of fifteen miles above its mouth. It also forms groves or narrow belts on the borders of nearly all the lakes and creeks. With these exceptions the whole county, including both its smooth areas of nearly level till, and its rolling and prominently hilly tracts of the same glacial drift in moraines, is prairie, destitute of trees or shrubs, and bearing everywhere luxuriant grass.

The species of forest trees found in Faribault county, in the estimated order of their relative abundance, according to Mr. Alex. Halliday, proprietor of the Verona Star mills, are bur oak, slippery or red elm, soft maple, box-elder, wild crab-apple, black walnut, bitternut, common poplar, or American aspen, the large-toothed poplar, and cottonwood, common; black oak, white or American elm, sugar maple, and June-berry, less common; black cherry, white ash, hackberry, and butternut, scarce; Kentucky coffee-tree, rare. The species of shrubs are stated by the same authority to be prickly ash, black currant, and hazel, abundant; frost grape, climbing bitter-sweet, smooth sumach, thorn, rose, wolfberry, and elder, common; choke-cherry, red raspberry, and prickly and smooth wild gooseberries, less common; the wild red cherry, and the black raspberry or thimbleberry, scarce. Mr. Halliday has seen cottonwoods and black walnut trees in this county five feet in diameter.

GEOLOGICAL STRUCTURE.

Faribault county has no outcrop of the bed-rocks that underlie the drift, but at five places wells have penetrated the drift and gone considerable depths into rock beneath. These are at Winnebago City, Easton, Minnesota Lake, Wells, and in Seely township. Their sections are as follows:

Winnebago City mills, a steam flouring mill; hight about 1,095 feet above the sea: well, 230 feet deep; soil, 2 feet; yellow till, 18 feet; blue till, 140, containing occasional beds of sand, from a few inches to five feet in thickness; stratified sand, probably modified drift filling a pre-glacial valley, 40 feet; yellowish and reddish magnesian limestone, 30 feet, the top of this rock being approximately 900 feet above the sea. Two other wells in Winnebago City go 150 and 160 feet in till, finding no bed-rock.

Terhurne & Scheid; Easton; hight about 1,050 feet: well, 205 feet deep; till, 101 feet, including layers of sand one to two feet thick, to rock at approximately 950 feet above the sea; consisting of whitish limestone, 8 inches; thin-layered, gray rock, probably also limestone, 2 feet; light gray sandstone, 101 feet, and extending below, coarsely granular, in some portions quite hard, quickly dulling the drill. This well was made with the expectation of obtaining an artesian flow.

Water was struck in the two feet of thinly bedded rock next above the sandstone, and rose to seven feet below the surface, but no considerable supply of water was found in the drift, and none additional in the sandstone.

Chauncy Barber; Minnesota Lake; at hight of about 1,040 feet: well, 140 feet deep; yellow till, 10; soft blue till, 80, to top of rock at approximately 950 feet above the sea; then, whitish limestone, 3 feet; thin-layered rock, probably limestone, 2 feet; soft, green shale, 2 feet; and gray sandstone, 43 feet, and extending lower. No water was found in the rocks below the drift.

C. W. Thompson; one mile west of Wells; about 1,140 feet above the sea: well, 153 feet deep; yellow and blue till, 117 feet; then, gray sandstone, 34 feet; softer, whitish shale, 2 feet; supply of water, insufficient. The top of this sandrock is approximately 1,025 feet above the sea. Another well, near by on the same farm, is 118 feet deep, and found soil, 2 feet; yellow till, 10; blue till, soft and sticky, 106 feet, excepting three feet of quicksand, with a little water, at about seventy-five feet from the surface; from sand or sandstone at the bottom water rose in this well to fifteen feet below its top.

In the twenty or more flowing wells, or fountains, at Wells, bed-rock is struck at 110 to 120 feet below the surface, or about 1,040 to 1,050 feet above the sea; and as soon as the thin stratum of the rock is pierced, water rises to the surface and five feet to fifteen feet above it. The section here is till, holding occasional layers of sand one to four feet thick, to a depth of 110 to 118 feet; then a stratum of yellowish or straw-colored rock is encountered, and after drilling into this a few inches or one or two feet, it appears that a vein of water one to six inches in thickness is found, not in gravel and sand but filling a cavity of the rock, from which the artesian flow comes. If the pipe is driven farther after reaching the water, it directly strikes upon rock below and the flow of water is shut off. No specimens of the stratum next above the water were obtained, but from the descriptions of well-makers and others it appears to be a limestone or a hard, sandy shale. It lies above the sandstone of Mr. Thompson's well, and the water probably lies at the junction of these beds, being held down by the impervious upper rock. The greatest thickness of the rock was at the vinegar factory, about one and a half miles south of Wells station, and probably ten feet higher, where a thickness of five feet of the yellowish limestone or shale were passed through at the depth of 110 to 115 feet. Water was found immediately under this, and rose to three feet below the surface. In rare cases this rock is not found before reaching the water supply, as in W. W. Woodard's well, in the south part of Wells, and on the highest land within the limits of this corporation, where the section was soil, 2 feet; yellow sand and clay, 6 feet; fine sand, 2 feet; yellow till, 10; blue till, 97, containing occasional beds of sand from two inches to two feet in thickness, yielding no water, till reaching the bottom at 117 feet, whence, without striking the usual layer of rock, an artesian flow of water rose to five feet above the surface. The beds of sand found in the till here are not persistent, as shown by two wells at A. L. Taylor's stable, one of which went through some four feet of sand at the depth of about sixty feet, while another boring twenty feet distant encountered only till or boulder-clay in this portion of its depth. In two instances, at Mr. Taylor's stable and at the Wells House, the bark of trees was found near the base of the drift deposits, 112 to 115 feet below the surface, but no shells nor other organic remains have been reported from these wells, which are usually bored two inches in diameter. Rarely these borings at Wells fail to secure an artesian flow, and in one of this kind Mr. P. Morse, well-maker, informs me that he went to a depth of 148 feet, the section being till 115 feet, and then sand, probably soft sandstone, for the remaining 33 feet, not passed through at this depth.

The only other point at which the bed-rock has been reached in this county is A. B. Brant's well, in the S. W. ¼ of section 4, Seely, close to Clayton post-office, which was bored 123 feet deep in hope of an artesian flow of water. This was soil, 2 feet; yellow till, 10; softer, moist, blue till, 80; harder blue till, 3 feet; bluish gray limestone, 28 feet, changing to lighter gray below, not penetrated. The top of this rock is estimated to be about 1025 feet above the sea. The only water obtained is from thin veins of sand which occur at various depths in the till, and it rises to four feet below the surface.

From the strike, dip, and hight of the rocky strata which outcrop in Blue Earth county and farther to the northeast and east, we may decide

with much certainty that the rock of the Winnebago City well is the Shakopee limestone; and that the sandstone of the wells at Easton and Minnesota Lake belongs to the next higher formation, the St. Peter sandstone, still retaining in these wells a thin cap of the Trenton limestone, which directly overlies this sandrock at Minneapolis and throughout southeastern Minnesota.

The southeastward dip of these rocks, which carries them, with all the higher Silurian formations, beneath the Devonian limestone of Worth and Cerro Gordo counties in Iowa and of Mower and Fillmore counties in this state, makes it improbable that the limestone or shale and underlying sandstone encountered at Wells are the same with those of Easton and Minnesota Lake. But the Palæozoic series in this state and Iowa has no thick beds of sandstone above the St. Peter; and the next geological age which is represented in this region by such deposits is the Cretaceous. We seem obliged, therefore, to refer to this age a formation of white sandstone, about 60 feet in thickness, enclosing a layer three feet thick of limestone and yellow shale at 21 to 24 feet below its top, which is found in the deep well at Owatonna, succeeded below by the limestones and shales of the Trenton group and the St. Peter sandstone (page 398). The same Cretaceous sandstone appears to be the bed-rock struck by wells at New Richland in southeastern Waseca county (page 410), half-way from Owatonna to Wells; and at the latter place it seems probable that the layer penetrated by its artesian wells corresponds to the limestone and shale enclosed in the Cretaceous sandstone at Owatonna, while this sandstone lies next below and is found in C. W. Thompson's well to have a thickness of at least 34 feet. The top of the strata which thus appear to be a continuous Cretaceous formation has the following hights, approximately, above the sea: in the Owatonna well, 1111 feet, the included limestone and shale being found at 1090; at New Richland, 1070; and at Wells, 1040 to 1050. These places lie in a straight line, the distance southwest from Owatonna to New Richland being eighteen miles, and to Wells thirty-four miles.

Respecting the age of the limestone found in the well of section 4, Seely, we can only say that the known stratigraphy and topography of the region indicate that probably it belongs to either the Galena or Niagara formations, intermediate between the Lower Trenton and Devonian, while

it may possibly represent either of the last. The nearest natural exposure of any rock older than the drift is thirty miles distant to the southeast, being on Lime creek in southwestern Worth county, Iowa. There the Hamilton limestone of Devonian age is found, and extends thence southeast to the Mississippi, having abundant outcrops along the Shell Rock and Cedar rivers.

Indications of the existence of Cretaceous beds containing lignite are reported to have been found in the S. W. ¼ of section 11, Verona. Mr. John Crapsey states that a great number of pieces of lignite, up to eight inches in diameter, were obtained by him there from the drift or talus forming the lower part of the east bluff of the Blue Earth river, a little above an island; and that near by the bed of the river seems to be a ferruginous sandstone or conglomerate. It is interesting to compare this with Prof. Bechdolt's observation (page 435) that fragments of lignite occur frequently in the alluvium of this river at its mouth. The layers of Cretaceous lignite in Minnesota, however, are too thin to be of value as a source of fuel; though they have supplied fragments found sparingly in the drift throughout the western two-thirds of the state.

Drift and contour.

The thickness of the drift upon this county probably varies from 75 to 200 feet, averaging 125 or perhaps 150 feet. It is composed mainly of till, which encloses occasional veins and beds of gravel and sand, and shows the same differences in color, hardness, and other characters, that have been mentioned more particularly in the report of Blue Earth county.

In northeastern Faribault county, the east half of Foster has a moderately undulating surface, composed of till, excepting occasional knolls or mounds of gravel and sand. From Freeborn lake to Wells, and thence north, northwest and west, to the north line of the county, to Minnesota and Lura lakes, and to Easton, the surface is very smooth and flat or more commonly somewhat undulating till, the descent of five to fifteen feet from the highest portions to the shallow depressions of sloughs being by long slopes. This area includes the west two-thirds of Freeborn and Carlston in Freeborn county; and, in Faribault county, all of Dunbar and Minnesota Lake, Clark, excepting its southwest corner, the northeast part of Walnut Lake, and nearly all of Lura, except part of its southwest quarter.

Again, on the other side of the moraine which extends northwestward from Kiester, flat or only slightly undulating till covers the southern and western parts of the county. Blue Earth river and its East fork have their course nearly along the center of this tract, from the west side of the Kiester hills westward to Blue Earth City, and then north by Winnebago City into Blue Earth county. The townships in this area are Seely, Brush Creek, Rome, Emerald, the southwestern half of Barber, Elmore, except a width of one to one and a half miles on its south side, Blue Earth City, Prescott, Delavan, Pilot Grove, except a width of one and a half miles on its south side, Jo Daviess, Verona, and Winnebago City.

*Glacial lake in the basin of the Blue Earth river.** The contour in these townships, as also in the northeast part of this county, in southwestern Waseca county, and through most of Blue Earth county, is generally quite flat, the drift being spread with an unusually smooth and even surface, nearly as in the Red river valley. The material of all these tracts is till,

*First described in the ninth annual report, page 341.

or a gravelly and stony clay. At many places, however, in western Faribault county and in Blue Earth county, its upper ten feet is found to be in part obscurely or sometimes quite plainly stratified. In this characteristic, also, it resembles the till which generally forms the surface of the south end and of the sides or outer portions of the flat Red river valley, which was covered by lake Agassiz during the recession of the ice-sheet.* Much of the basin that is now drained northward by the Blue Earth river, distinguished thus by its smoothed and sometimes partly stratified till, appears to have been occupied by a similar glacial lake, dammed by the barrier of the waning ice-sheet of the last glacial epoch during a considerable time in which this was retreating northward and northwestward from the south line of the state and from its eastern moraine, until its recession uncovered the present avenue of drainage to the northeast by the Minnesota river. The hight of this lake was approximately 1150 feet above the sea, making its depth in the north part of Faribault county 50 to 125 feet, on the west line of Waseca county about 75 feet, and in the north part of Blue Earth county about 200 feet. Its exact boundary can probably be traced, with the aid of leveling, along considerable portions of its eastern, southern and southwestern shores, by its beach deposits of gravel and sand. When this lake attained its maximum extent, it is believed to have spread far to the northwest beyond the limits of the basin of the Blue Earth river.†

The outlet of this glacial lake is found in Kossuth county, Iowa, at the head of the most southern branch of the Blue Earth river, where Union slough‡ occupies a continuous channel from the headwaters of the Blue Earth to Buffalo creek and the East fork of the Des Moines. It is stated that at the time of high water an uninterrupted canoe voyage has been made by this route from Algona on the East Des Moines river north to Blue Earth City. Union slough (also frequently called the "Big slough"

*Compare the eighth and eleventh annual reports.

†At time of formation of the moraine that reaches from Kiester northwestward (page 462), this lake probably bordered the ice-sheet from Faribault county to Yellow Medicine county, having a length of about one hundred and twenty-five miles, with a width varying from five to fifteen miles, its area being thus about one thousand square miles. By the farther recession of the ice the size of the lake was greatly increased, so that it probably attained a length of one hundred and sixty miles, from Waseca to Big Stone lake, with a width of forty miles in Blue Earth and Faribault counties, but of only twenty miles or less in the upper part of the basin of the Minnesota river. Its area at this maximum stage appears to have exceeded three thousand square miles. The first outlet obtained at a lower level than Union slough in Iowa, and therefore reducing the depth and area of this lake, was doubtless in the vicinity of Elysian and Waterville in Le Sueur county, passing to the Cannon river, at a hight about 1075 feet above the sea, but afterward by a different avenue some fifty feet lower. A large area in Blue Earth, Brown, Nicollet, Sibley and Le Sueur counties, was probably covered by this lake while it outflowed to the Cannon river, until the retreat of the ice from the moraine at Elysian in Le Sueur county to that at Waconia in Carver county, uncovered the lower part of the Minnesota valley and permitted drainage to take its present course.

‡Compare Dr. C. A. White's *Report on the geological survey of Iowa*, 1870; vol. i, p. 57.

by settlers on its east side) lies in the east part of township **98**, and in sections 3, 4 and 9, of township **97**, range **28**, its length being about eight miles in a course first south and then south-southwest. Its width is from one-eighth to one-fourth of a mile, with enclosing bluffs which rise steeply twenty to thirty feet to the general surface of moderately undulating till on each side. The bottom of this glacial channel along the Union slough, where its descent was southward, is now mainly occupied by a marsh, because of the partial filling up of its continuation, since the ice age, by Buffalo creek. Along the head-stream of the Blue Earth river, from Union slough to the state line, this channel has a width of about an eighth of a mile, and is twenty-five to thirty feet below the average surface at each side, to which the ascent is by moderate slopes.

This valley, eroded by outflow from the glacial lake of Faribault and Blue Earth counties, soon changes upon the smoothed area covered by that lake to channels eroded since the glacial period by the present drainage. Thus the excavation by this branch of the Blue Earth river in Elmore is thirty to forty feet deep, and has steeper banks, but is narrower, than the valley in which it lies farther south. Northward, the lacustrine area, otherwise a vast plain, has become deeply eroded by the Blue Earth river and its tributaries.

Moraines. Exceptions to the generally smooth and nearly level contour of the drift are found in two rolling and hilly tracts, one in the eastern half of the county, the other on its southern edge. The most conspicuous elevations in this part of the state are the drift hills in Kiester township. This tract is closely joined with the inner or western of the two approximately parallel terminal moraines, which extend from north to south across Freeborn county, and which were accumulated at the east side of the vast lobe of the ice-sheet that in the last glacial epoch covered the basin of the Minnesota river and reached south to central Iowa. The drift upon this ice-covered area was left with a very smooth, slightly undulating surface, while its borders are marked by morainic belts of hilly and knolly drift. These hills in Kiester appear to indicate that the ice-margin here became indented by a re-entrant angle between two confluent ice-currents. Northwest from Kiester, a belt of hilly or more or less rolling drift reaches twenty miles, to the southwest part of Lura; and ten miles beyond appears

to be represented by a hilly and rolling tract in the southwest part of Sterling, in Blue Earth county. The first opinion of the writer, stated in the ninth annual report, that this morainic belt was formed wholly as a medial moraine by converging ice-currents, seems questionable. Further exploration is needed to determine whether it is not instead a terminal moraine, accumulated on the southwest side of this ice-lobe, after three distinct times of recession from its outermost limit. This explanation is strongly confirmed by comparison with the three similar morainic belts beyond this toward the south and southwest, all of which are apparently terminal, as shown in the report of Watonwan and Martin counties.*

The most hilly portions of Kiester are its south side for a width of one mile, and a belt through its northeast part from section 13 to sections 3 and 4, in which are the most prominent of these hills, visible fifteen miles to the north and west. Their hight is from 100 to 200 feet above the lowland in these directions and above Bear lake in Freeborn county; the highest points, which are in the S. W. ¼ of section 3, being about 1400 feet above the sea. These are massive hills of till, of irregular outlines, but trending somewhat more from east to west than in other directions. Between the hill-ranges of the north and south parts of this township, its central portion for a width of two or three miles is only moderately undulating till, reaching east at the head of Brush creek to the west border of the plain of modified drift in Mansfield, Freeborn county. In sections 8, 17, 20 and 29, through the west part of Kiester, a series of hills of till, 60 to 75 feet high, connects the west ends of these ranges and forms the west border of the lower tract between them, except at the gap through which Brush creek flows.

In Foster, the township next north of Kiester, boldly rolling hills of till fifty to seventy-five feet high extend from section 28 to the north and northwest by Rice lake, where they occupy a width from one-half mile to one mile on each side of the lake. Still farther northwest the same contour and material border the east, north and west sides of Walnut lake, including the most of sections 25 to 28, and 33 to 36, of Walnut Lake township. The land south of Walnut lake is low and gently undulating till, with frequent marshes. In Barber, the township next west, a prominently rolling tract is found about the little lakes in sections 14, 15, 22 and 23. The material here is till, and its swells or hills are thirty to fifty feet above the hollows. Through six miles thence northwest a more or less rolling surface of the unmodified glacial drift continues in a belt about two miles wide, to the southwest part of Lura and the east edge of Delavan. On the railroad it is crossed in the first three or four miles east of Delavan, where its swells are twenty-five to forty feet high, not crowded and thickly set, but generally in long slopes, with no prevailing trend. This morainic belt divides two extensive areas of till, which are characterized by a very smooth and flat surface.

In the south edge of Elmore and Pilot Grove a width from one to one and a half miles is hilly or prominently rolling drift, and forms part of a

*In this connection it is important to note that Prof. N. H. Winchell in 1871 and 1872 observed four terminal moraines, which similarly appear to have been formed at the farthest limit and successive stages in the recession of a lobe of this ice-sheet covering the area of lake Erie and extending thence southwestward These moraines, explored in northwestern Ohio and adjacent parts of Indiana and Michigan, are named the St. John's, Wabash, St Mary's and Blanchard ridges (*Proceedings of the Am. Assoc. for Adv. of Science*. vol. xxi, 1872, pp. 160–177; also, *Report of the geological survey of Ohio*, vol. ii, 1874). Again, Prof. T. C. Chamberlin observed three distinct morainic belts belonging to this epoch, divided by smoother tracts, in a section between Black Brook (T. 32, R. 16) and St. Croix Falls, at the west side of Wisconsin (*Geology of Wisconsin*, vol iii, 1880, pp. 384 and 385).

If this be a fourth terminal moraine, its continuation northwestward is probably traceable to the vicinity of Big Stone lake. My observations of the area across which it would lie, make it certain that no very prominent accumulations of morain e drift occur there; but suggest that this formation should be searched for in a course extending by Madelia, near lake Hanska, Sleepy Eye creek, and the northwest corner of Redwood county, to the southwest part of Tyro in Yellow Medicine county, and thence to the eastern morainic belt in township 119, range 46, Lac qui Parle county. The glacial lake before mentioned would extend along this ice-border, through Watonwan, Brown and Redwood counties, covering an area several miles wide in the depression between the ice-sheet and the Coteau des Prairies. Its first interruption by land higher than 1150 feet above the sea would be in Yellow Medicine county, where a fourth morainic belt was observed, with a great water-course of some former time at its west side.

belt of similar contour, which seems to be a terminal moraine, reaching in Iowa through the north part of Hancock county, southwestern Winnebago, and northeastern Kossuth county, into Minnesota.

The most noteworthy hill of this area in Elmore is in the north part of section 32, rising 50 to 60 feet and about a sixth of a mile long, trending from east to west. In the south part of sections 25 and 26, Pilot Grove, hillocks and short ridges form a somewhat continuous east-to-west series, 40 to 50 feet high. These accumulations are chiefly till, differing from its level or moderately undulating tracts in a greater abundance of boulders; but occasional knolls, sometimes the highest of their vicinity, are composed of obliquely stratified gravel and sand. In sections 29 and 32, Pilot Grove, these morainic deposits are inconspicuous or wanting; next they rise to the hight of 30 to 40 feet in section 31 and the south half of section 30, at the southwest corner of Faribault county; and thence they occur scatteringly all the way northwest to East Chain, and less prominently to Fairmont. In this distance their material, and that of the whole region about them, is till. Their contour is seldom rough, but rises in swells, 25 to 50 feet above intervening depressions, with trends most frequentiy from northwest to southeast.

Modified drift. Kames occur three miles south of Walnut lake, in section 23, Brush Creek. They consist of short northwest to southeast ridges and round or conical knolls, steep-sided, about twenty feet high, composed of coarse gravel and sand, and form a series three-fourths of a mile long. The region surrounding them is slightly or moderately undulating till. A portion of the moraine, situated in sections 16 and 8, Walnut Lake township, two and a half to five miles northwest of the lake, is formed of kame-like deposits, accumulated in swells, knolls and northwest to southeast ridges, thirty to forty feet high, of very gentle slopes, composed mainly of stratified sand and fine gravel, as shown by wells, which do not reach the bottom of this modified drift at the depth of fifty feet.

Alluvium. The stratified clay and sand used for brick-making at Blue Earth City, and other similar beds of small extent, appear to be alluvium laid down along the avenues of drainage after the glacial lake that had covered this area was withdrawn by the departure of the ice-sheet which had been its northern barrier.

Pebbles and boulders. On the Kiester hills pebbles and boulders occur more plentifully than on the lowlands, but are not usually very abundant, and blocks more than five feet in diameter are rare. About one-twentieth part of the large boulders and probably one-fifth of all the pebbles are limestone, often obscurely fossiliferous. The greater part of the rock-fragments, especially the larger blocks, are granite, syenite, gneiss and crystalline schists. One boulder, ten feet long, of garnetiferous hornblende schist, was noted here. A greenish slaty rock is also sparingly

represented. Only a few pieces of the red Potsdam quartzyte, which outcrops near New Ulm and southwestward, were seen, the largest being one foot long. No conglomerate was found. It is noticeable that a considerable proportion of the pebbles upon these hills of till are water-rounded, and that some have the flattened, discoid form which is characteristic of the stones of a shingle beach, worn by sliding with the rise and fall of the waves, rather than by being rolled in the channel of streams, which gives more commonly a somewhat spheroidal shape. These water-worn stones are evidence that the ice-sheet gathered much of its drift from pre-glacial valleys and lake shores, lifted these gravels of ancient rivers and beaches into its mass, and at its border and during its final melting deposited them as constituents of the till and modified drift.

Wells in Faribault county.

The following records of common wells afford further illustrations of the composition and order of the drift deposits.

Clark. The sections before described in Wells and its vicinity are in this township.

Foster. John Shequen; sec. 14: well, 18 feet; all sand; plenty of water.

M. Butler; S. E. ¼ of sec. 15: well, 30 feet; soil, 2; yellow till, 26; gravel and sand, with small amount of water, 2 feet; blue till below.

R. D. Taylor; N. E. ¼ of sec 21: well, 22; soil, 2; yellow till, 12; gravel and sand, 8.

Kiester. John Harvey; S. W. ¼ of sec. 31: well, 45; soil, 2; yellow till, with gravelly streaks, 12; gravel and sand, ½ foot; blue till, very hard at top for one foot, then moist and soft below, 31. This well has only seep water from the lower part of the yellow till.

A copious spring, much resorted to by cattle, slightly chalybeate, issues near the middle of sec. 14, upon land twenty-five feet higher than neighboring depressions and a hundred feet below the highest hills near at the northeast and northwest.

Mr. E. Porter, well-maker, of Lake Mills, Iowa, states that in the south part of Kiester the upper till, yellowish in color, is usually 8 to 10 feet thick; underlain by sand, 1 to 8 feet in thickness; succeeded by dark bluish till, called "hardpan", much harder than the upper till. Generally, however, it has been his experience that the yellow till is more stony and harder to bore or dig in than the underlying blue till, which is moist and sticky. The greatest thickness of yellow till found by him is twenty-five feet. He has frequently found fragments of lignite, but no unchanged wood nor shells.

Seely. I. M. Riker; N. E. ¼ of sec. 10: well, 30 feet; soil, 2; yellow till, 8; blue till, soft and sticky, 20; water rose ten feet from gravel and sand at the bottom.

A. B. Brant's well in sec. 4, reaching to the bed-rock, has been described on page 458. H. W. Everett, well-maker, states that the yellow upper till of this region almost always contains sandy streaks and seep water, while these occur less frequently in the blue till, which is moister and softer, and has fewer rock-fragments, than the till above. The greatest thickness of the yellow till, found in boring fifty wells, is 20 feet; and the greatest depth bored by him in the blue till is 70 feet. A dark "hardpan", much harder than either of these tills, is frequently found, varying from one to five feet in thickness, always lying under a considerable depth of the soft and moist blue till. Mr. P. Morse, of Wells, and W. Z. Haight, of Winnebago City, well-makers, agree with the foregoing as to the characters and order of the three distinct kinds of till generally met in deep wells throughout this county. Mr. Morse reports the maximum thickness of the dark hardpan, as found by him, to be 12 feet. Mr. Haight has found the yellow color of the till extending deepest on swells; while it is thin or wanting in depressions. Its maximum depth found by him is 50 feet; the greatest thickness of the soft, blue till, 50 or very rarely 75 feet; and of the darker till or hard-

pan, which almost invariably is overlain by a considerable thickness of the last, 10 feet. Small pieces of lignite, derived from Cretaceous strata mingled with the drift, are frequently found; but no shells, and no interglacial peat nor wood.

Brush Creek. Gustav Buscho; sec. 8; well, 20; soil, 2; yellow till, 4; quicksand, 1 foot; blue till, moist and sticky, yet harder than the upper till, 13 feet; water rose five feet from a vein of sand at the bottom.

Walnut Lake. C. F. Zimmerman; S. E. ¼ of sec. 4; well, 32 feet; soil, 2; yellow till, 15; harder blue till, 15; water rose in a half day twenty-five feet from sand at the bottom.

O. A. Odell, sec. 8: well, about 50 feet deep; all stratified gravel and sand.

C. S. Bates; S. W. ¼ of sec. 15: well, 30 feet; soil, 2; a marly layer, 1 foot; fine gravel, containing pebbles up to two or three inches in diameter, and sand, 27; water abundant, fifteen feet deep. The two last are upon the high rolling tract of modified drift, apparently of kame-like origin, which forms part of the moraine. Mr. Morse has bored to a depth of 166 feet in this township, about two miles north of Walnut lake, not reaching the bottom of the glacial drift.

Minnesota Lake. Chauncy Barber's well, near the depot, going through the drift into the bed-rocks, has been before described.

Lura. Also see a preceding page for Terhurne & Scheid's well, at Easton, in sec. 36. John E. James; Easton: well, 70; soil, 2; yellow till, 15; softer blue till, 53; water rose forty-five feet from sand at the bottom. Watson Cole, in the S. E. ¼ of sec. 32, has bored 160 feet, but the strata passed through were not learned.

Mr. Haight reports that in boring a well in this township, about two miles north of Easton, he met, at 60 feet below the surface, a layer of mixed sand and grass-leaves, appearing like drifted grass on a sandy beach. This was between beds of till, and marks an interglacial epoch; but no other testimony of this kind was obtained in Faribault county.

Barber. Andrew Wesner; sec. 22: well, 20; soil, 2; gray till, 5; blue till, 5; yellowish gravel and sand, 8 feet, with water in its lower portion.

Emerald. Fred Weber; sec. 10: well, 24 feet; soil, 2; yellow till, 4; blue till, soft and sticky, 18; no gravel nor sand layers; water seeps from the upper till, and is very scanty in a dry season.

F. Dreblow; Ewald post-office, sec. 30: well, 22; soil, 2; gray till, 2; blue till, 18; seep water only.

Elmore. Caleb McCarther; in southeast part of this township: well, 81 feet; soil, 2; yellow till, 18; harder blue till, 60; coarse gravel, 1 foot; from which water rose eighty feet, stopping at one foot below the surface.

Blue Earth City. George McCarther; in the city: well, 92 feet, being the deepest within the corporation; soil, 2; yellow till, 18; harder, dark till, 50; stratified gravel, sand and clay, 22; water rises, attaining a depth of fifty feet.

The railroad well here is 68 feet deep, finding soil and yellow till, 20 feet; blue till, 48 feet; with water rising from the bottom thirty-five feet. The elevator, close north of the last, has a well 36 feet deep, containing twenty feet of water.

Joseph Schimek, S. E. ¼, sec. 20; well, 44 feet; soil, 2; yellow and blue till, 42; only seep water. In another well, a quarter of a mile farther east, water rose forty feet from the bottom. G. B. Franklin, well-maker, states that the yellow till in this township is commonly 10 to 20 feet thick, its lowest foot being very hard, cemented by iron-rust. This is succeeded below by 15 to 20 feet of soft, bluish till, which in turn is underlain by a darker, harder, and more stony till, called "hardpan."

Delavan. H. E. Mayhew; at the village and depot, in sec. 36; well, 60 feet deep; yellow till, 15; soft blue till, 45; water rises from sand at the bottom to twenty feet below the surface.

Winnebago City. W. H. Holley; in the city: well, 96 feet; soil, 2; yellow till, 15; soft, blue till, 74; dark hardpan, with many limestone pebbles, 5 feet; water rose fifty feet from sand and gravel at the bottom. The ten bushels of this sand and gravel which were drawn up contained about a peck of lignite in small fragments. Mr. W. Z. Haight supplied the record of this well; as also of the deep well at the Winnebago City mills, which reaches into the bed-rock, as before described. He states that in the vicinity of this city the order of the drift deposits is generally as follows: yellow till, about twenty feet; soft, blue till, 30 to 50 feet, becoming near its base a lighter

bluish or brownish, soft mud, of fetid smell, 1 to 6 feet thick; and from this there is a change in two to five feet to the dark, very hard till called "hardpan," which is the hardest, most compact and most rocky of these tills.

Verona. John G. Pace; sec. 24: well, 44 feet; soil, 2; yellow till, 15; blue till, 16; gravel, sand and clay, 11; water rose ten feet.

Alex Halliday; at Verona Star mills; sec. 24: well, 45 feet; soil, 2; yellow till, 8; much harder dark till, 35; water rose nine feet from sand at the bottom.

Pilot Grove. Dr. G. D. Winch estate; sec. 8: well, 100 feet; soil, 2 feet; yellow till, about 5 feet; all below was blue till, about 93 feet, with few sand layers; at the bottom was sand, from which water rose ninety feet.

Pitt Wilson; S. W. ¼ of sec. 20: well, 70 feet; soil, 2; yellow till, 18; harder blue till, 50; water rose from quicksand at the bottom, and after one and a half hours flowed from the top of the well.

MATERIAL RESOURCES.

Agriculture must always continue the leading industry, as it unfolds the most valuable natural resources of this county. We have here to speak briefly of its water-powers, brick-making, peat, and artesian fountains.

Water-powers. Five water-powers are used in Faribault county, all situated on the Blue Earth river and employed by flouring mills, in descending order as follows:

Blue Earth City mills; N. Dustin & Co.; just below the junction of the east and west branches of the river, in the west part of sec. 8, Blue Earth City; head, about nine feet.

Verona Star mills; Alex Halliday; at the west line of sec. 24, Verona; head, eight feet.

Rising Sun mills; at the bridge in the S. W. ¼ of sec. 11, Verona; head, eight feet.

Banner mills; C. H. Payne & Son; at the bridge in sec. 33, Winnebago City, one and a half miles west from the town; head, nine feet.

Woodland mills; Dorsey Brothers; sec. 3, Winnebago City; head, about eight feet.

Bricks. Brick-making was begun at Blue Earth City in 1867, and was carried on nine years; but nothing was done in this work here in the years 1876 to 1879. This yard, owned by S. P. Childs, was leased in 1880 to Christian Severson, who expected that season to make 600,000 bricks, selling them at $8 per M. The mixed wood used for the kilns formerly cost $5 per cord, but is now furnished by the railroad at $3½ to $4. The bricks made here are red, of good quality, tempered by intermixture of one-sixth as much sand as clay. The excavation is in the south or right bank of the West branch of the Blue Earth river, about a quarter of a mile southwest from its junction with the East branch. The clay has a thickness of 25 to 35 feet, and at a few feet above the river is underlain by sand. The upper four to six feet of this clay are obscurely stratified. Its next ten feet are divided, similarly with the clay-beds at Carver and Jordan in the valley of the Minnesota river, into layers of light grayish color, composed of clayey and sandy fine silt, changing above and below to a nearly black, more unctuous and finer clay, which forms the partings between them. In the east part of this excavation the thickness of these layers is from a half inch to one inch, but within three rods to the west they are from one to six inches thick, being thinnest at the top. They are somewhat contorted or wavy, but in their whole extent are nearly level. The alternating conditions which produced these successive layers are believed to have been the yearly changes of the seasons, the principal mass of each layer being the deposition of the annually recurring periods of high water, and the darker partings being the sediment of a current of reduced volume and therefore slower and less turbid. The lower eight or ten feet of this clay are finely and obliquely laminated and very sandy. A well, 38 feet deep, at the top of this bank, even in hight with the brick-yard, finds the clay gradually become more sandy, and its last four feet are in clear sand, containing water at nearly the same level as the river.

In section 11, Verona, at the Rising Sun mills, a kiln of 130,000 red bricks was made by Westbrook & Ferguson in 1879, not with satisfactory success because of particles of limestone contained in the clay and sand, which after burning become slacked and crack the bricks. The clay used here is yellow, imperfectly stratified, apparently a part of the till, occurring in the northeast bluff at 15 to 30 feet above the river. The proportions of clay and sand mixed for these

bricks was three and one. Bricks of the same color have been made also at several other places near the river in its next three or four miles below, with poor or sometimes fair results. The best have been from the recent alluvium of the bottomlands. Nothing has been done here in this business during the last few years, excepting the kiln just mentioned.

Red bricks of inferior quality, mostly somewhat cracked by particles of limestone, but otherwise durable, were made from 1870 to 1872, at the north line of section 8, Clark, about a quarter of a mile west of Wells, where they are seen in brick buildings. The material used was probably the obscurely stratified gravelly clay that often forms the upper part of the glacial drift upon this area which was covered by a lake while the ice-sheet was retreating across Faribault and Blue Earth counties.

Peat. In the second annual report of this survey, Prof. Winchell has treated of the peat of this state, the following details being given in respect to Faribault county.

Near Wells a slough on land of Clark W. Thomp son was found to have from four to six feet of peat, in part watery and fibrous, but mostly of good quality, underlain by a bed, six inches to one foot thick, of peaty mud and clay with shells and some sand. An analysis, by Dr. P. B. Rose, of Ann Arbor, Michigan, of this peat, after drying in the air, gave in 100 parts, 16 of hygroscopic water; 18 of ash; and 66 of organic matter. The ash, or inorganic matter, contained of silica 61.32 per cent.; lime, 12.44; carbonic acid, 10.69; iron and alumina, 9.71; magnesia, 2.43; sulphuric acid, 2.37; potassa, 0.55; soda, 0.23; and a trace of chlorine. The organic matter was made up of carbon, 51.94 per cent.; of hydrogen, 6.17; and of oxygen and nitrogen, 41.89. The heating power of a hundred pounds of this air-dried peat appears to be equal to that of ninety pounds of dry oak wood. The residue of ashes from peat is fifteen to twenty-five times greater than from an equal weight of wood.

Without some process of manufacture, or preparation for use by condensing its volume and forming it into blocks, peat is too soft and friable, and makes a slow, smoldering fire. In 1871 Mr. W. Z. Haight prepared peat for fuel at Wells, and it was considerably used by the locomotives of the Southern Minnesota railroad. This work was 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 are 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, cutting 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, conveyers, &c., 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 bot-

tom, 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 beds 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 [1871], 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 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. 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 company, at which price the yield per day would be $60.00." The value of the manufactured peat is estimated equal to that of good wood per cord; and the cost of the plant, capable of manufacturing 100 tons of wet peat, or 25 tons when dry per day, including mill ($400), frame, trestle-work, car-track, car, dump cart, etc., is stated to have been about $700. The demand, however, was too small to lead to the continuation of this business. Two or three years later Mr. Haight again worked peat in this manner near Easton; but here, also, the enterprise was soon abandoned, though a good fuel could be made at small cost, if sufficient quantities could be sold to keep the machinery and workmen employed.

An analysis, by Dr. P. B. Rose, of the peat manufactured by Mr. Haight at Wells, gave of water, 14 per cent.; ash, 18; and organic matter, 68. The ash yielded silica, 58.31 per cent.; lime, 14.18; carbonic acid, 11.63; iron and alumina, 10.21; magnesia, 2.90; sulphuric acid, 2.11; potassa, 0.41; and soda, 0.18. Of its organic matter, carbon was 52.02 per cent.; hydrogen, 6.68; and oxygen and nitrogen, 41.30. A hundred pounds of this peat was found equal in heating power to ninety-eight pounds of dry oak wood.

A peat deposit, eighty or a hundred acres in extent and said to reach a depth of four feet, occurs on land of H. F. Quinby and J. Robinson, in section 30, Minnesota Lake.

Near Easton peat is found in considerable quantities on land of W. Z. Haight. Four specimens of this peat, air-dried, were submitted to chemical examination by Prof. S. F. Peckham, as to their " 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:

	1.	2.	3.	4.
Hygroscopic water	13.04	10.99	20.64	16.75
Organic matter	48.64	44.56	53.60	47.03
Ash	38.32	44.45	25.76	36.28
Analyses of the ashes yielded:				
Silica (SiO_2)	83.13	83.35	72.79	80.55
Carbon (C)	.86	.03	.95	.75
Iron oxide(Fe_2O_3) and iron phosphate ($Fe_2P_2O_8$)	7.99	5.29	9.46	10.23
Lime (CaO)	5.44	7.39	5.92	5.61
Magnesia (MgO)	1.75	.97	6.13	.76
Sulphuric acid (SO_3)	.78	2.57	trace	1.34
Undetermined	.05	.40	6.25	.76"

Of these specimens the first was taken from a bog at eighteen inches below the surface; the second, from the same bog at three feet below the surface; while the third and fourth are from another bog near, respectively at the same depths of eighteen inches and three feet. Their values for heating, compared with that of an equal weight of dry oak wood, called 100, were found to be in the foregoing order, 64.0, 58.6, 70.5, and 61.7.

Artesian fountains. The remarkable flowing wells, or fountains, which are found at Wells, were discovered after the village had received this name in honor of a distinguished citizen. The section of the drift penetrated here, and the character of the bed-rock found at the bottom of these wells, from which their water rises immediately 110 to 120 feet to the surface and five to fifteen feet higher, have been sufficiently treated of under the head of the geological structure of the county. Most of these wells have been bored two inches in diameter, and reduced to a half inch or less at the top. The pipe is often prolonged above the surface, conveying the water into tanks. About twenty of these wells have been obtained within a radius of one mile. Their supply is large, but not inexhaustible; for, when Hon. M. S. Wilkinson's well was bored, a half mile north of the village and on land ten or fifteen feet lower, its two-inch stream, very copious, lowered the wells in the village so that their water no longer reached the surface. After this new well was reduced to a small flow, yet affording an abundance for all the requirements of house and farm, the water of all the other wells rose very nearly as high as before. If, therefore, the proposition which was once suggested, to tap this stratum of water by a large well for water-power to a grist-mill, had been adopted, the flow would have been found inadequate, while the water of the small wells would have failed to rise to the surface. This water is of excellent quality, very clear and cool; it is somewhat chalybeate, so that it gives a slight coating of iron-rust to wooden gutters and troughs.

The ground upon which these artesian waters are gathered and whence they receive the pressure that causes them to rise here above the surface, is probably Freeborn county, which begins four miles east of Wells, and extends thirty miles to the east, with an average elevation about a hundred feet higher above the sea. From this station the railroad rises 108 feet in going nine miles southeast to Alden; while its summit, six miles farther east, is 170 feet, and the depot at Albert Lea is 68 feet above Wells.

Other artesian fountains are obtained in this county from water-bearing beds of gravel and sand included in the glacial drift, at depths from thirty or forty to nearly a hundred feet. They are most frequent in Dunbar, Minnesota Lake and Lura, and especially near the Maple river through the second and third of these townships and through Mapleton and Sterling in Blue Earth county. Rarely artesian water is found farther to the south and southwest in Faribault county. The only instances learned of are Ole E. Johnson's well, about 90 feet deep, in the southeast part of Emerald, and two in Pilot Grove, one being on the farm that was owned by the late Dr. G. D. Winch, in section 8, about 60 feet in depth, which after overflowing four years ceased in the autumn of 1879, and the other being Mr. Wilson's, in the S. W. ¼ of section 20, which was sunk in 1880, 70 feet deep, and at the time of this examination had been running four months.

All these artesian wells, as also the common wells of the county, already described in treating of the glacial drift, invariably have good water, and nearly always in ample amount within twenty-five to fifty feet from the surface. It is, however, hard water, holding the carbonates of lime and magnesia in solution, and requires cleansing with ashes or otherwise before it can be satisfactorily used for washing with soap.

ABORIGINAL MOUNDS.

Numerous circular mounds, apparently artificial, one to one and a half feet high, and fifteen to twenty feet across, are seen near the road along a distance of three miles about half way between Freeborn and Wells; and a few similar mounds were seen in and beside the road two or three miles west of Wells.

Two mounds, twenty feet in diameter and one and a half feet high, occur at the south side of the S. W. ¼ of the S. W. ¼ of section 13, Brush Creek, about a third of a mile east of the bridge over the East branch of the Blue Earth river.

Again, in Kiester, two mounds of about the same size as the foregoing were noted near the middle of section 19.

In Mansfield, the most southwest township of Freeborn county, lying next east of Kiester, two or three such mounds were observed in the N. W. ¼ of section 13; also, at the south side of section 34 of this township, close to the state line, are two or more of these small mounds. Passing the last, a road extends south into Iowa, and about a mile beyond the state boundary a mound of this form but two feet high, being larger than any of the others here mentioned, was seen six rods east of this road, with a second of the smaller size near it.

CHAPTER XV.

THE GEOLOGY OF WATONWAN AND MARTIN COUNTIES.

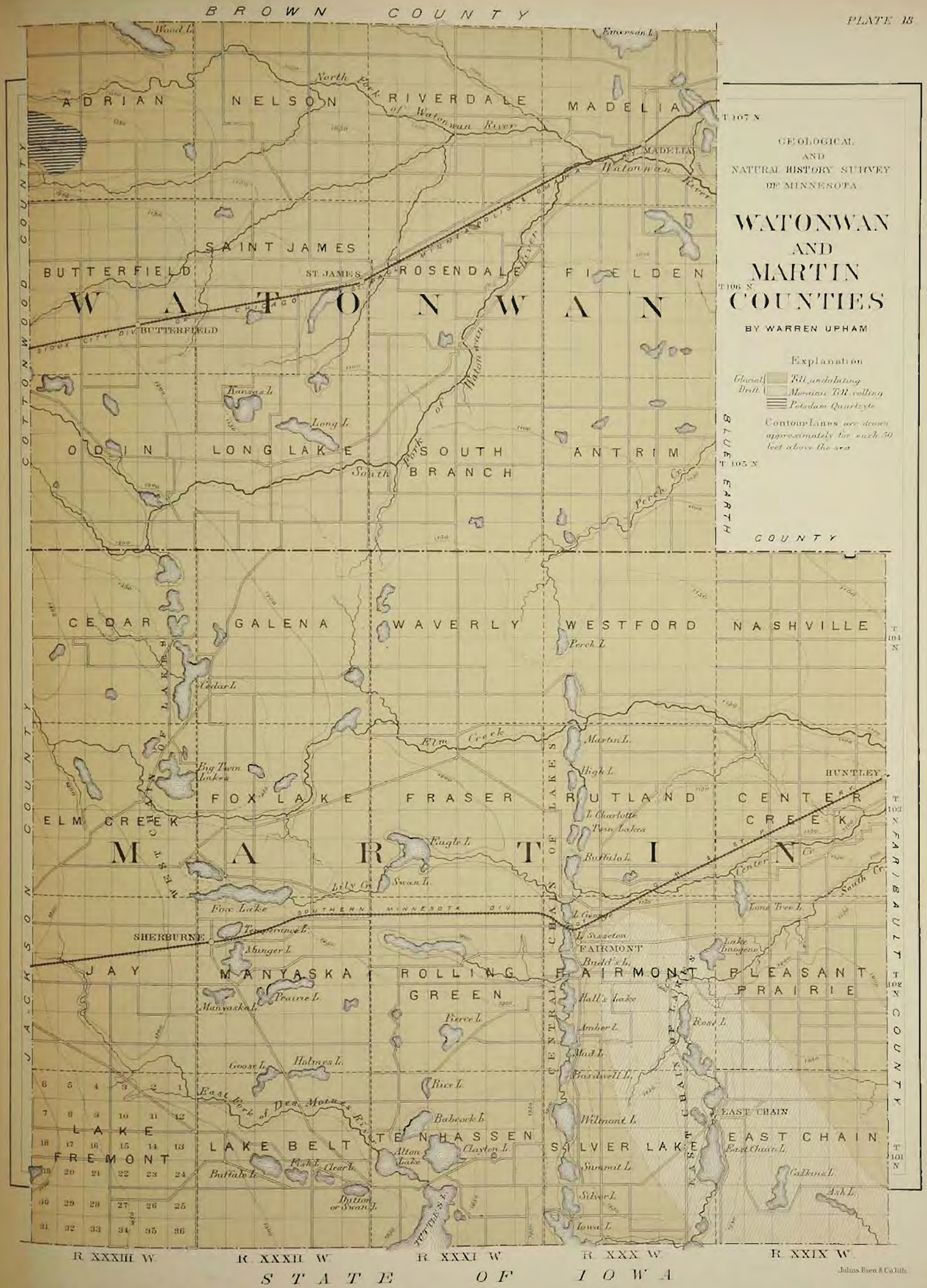
BY WARREN UPHAM.

Situation and area. Watonwan and Martin counties lie in southern Minnesota, the former being directly north of the latter, which borders on Iowa. They are a little west of the central meridian of the state. The distance of Madelia in Watonwan county southwest from Minneapolis and St. Paul is 87 miles; and Fairmont in Martin county is 27½ miles south, and two miles west of Madelia. From the east line of Martin county to the Mississippi at La Crosse is 150 miles; and from the west line of these counties to the line between Minnesota and Dakota is 80 miles.

Both these counties are rectangles, the extent of Watonwan being twenty-four miles from east to west and eighteen from north to south; while Martin county reaches six miles farther east, and is thirty miles long from east to west, with a width of twenty-four miles. The area of Watonwan county is 435.45 square miles, or 278,689.92 acres, of which 1,638 acres are covered by water. The area of Martin county is 723.89 square miles, or 463,288.40 acres, of which 12,267.35 acres are covered by water.

SURFACE FEATURES.

Natural drainage. Watonwan county is wholly drained by the river of the same name, which empties into the Blue Earth river about three miles below Garden City in Blue Earth county. The North and South forks of the Watonwan river, having their sources in Cottonwood county, traverse respectively the northern and southwestern parts of Watonwan county, each receiving several tributary creeks, and are united in one stream two miles west of Madelia, and about twenty miles, following the course of the


BROWN COUNTY
COTTONWOOD COUNTY
JACKSON COUNTY
BLUE EARTH COUNTY
FARIBAULT COUNTY
ADRIAN
NELSON
RIVERDALE
MADELIA
SAINT JAMES
BUTTERFIELD
ROSENDALE
FIELDEN
WATONWAN
ODIN
LONG LAKE
SOUTH BRANCH
ANTRIM
CEDAR
GALENA
WAVERLY
WESTFORD
NASHVILLE
ELM CREEK
FOX LAKE
FRASER
RUTLAND
CENTER CREEK
MARTIN
JAY
MANYASKA
ROLLING GREEN
FAIRMONT
PLEASANT PRAIRIE
LAKE FREMONT
LAKE BELT
TEN HASSEN
SILVER LAKE
EAST CHAIN
SHERBURNE
HUNTLEY
North Fork of Watonwan River
South Fork of Watonwan River
Watonwan River
Elm Creek
Perch Creek
Center Creek
South Cr.
Des Moines River
CHAIN OF LAKES
T 107 N
T 106 N
T 105 N
T 104 N
T 103 N
T 102 N
T 101 N
R XXXIII W
R XXXII W
R XXXI W
R XXX W
R XXIX W
STATE OF IOWA
GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA
WATONWAN AND MARTIN COUNTIES
BY WARREN UPHAM
Explanation
Glacial Drift
Till undulating
Morainic Till rolling
Potsdam Quartzyte
Contour Lines are drawn approximately for each 50 feet above the sea
Julius Bien & Co. lith.

Natural drainage.]

river, above its mouth. Antrim, the most southeast township of this county, is drained by Perch creek, which has its source a few miles farther south in Martin county, and flows northeast to the Watonwan river.

Among the *lakes of Watonwan county* the following are worthy of mention: Emerson lake, at the north side of Madelia, two miles long from east to west and one and a half miles wide, with about half its area in Linden, Brown county; five or six smaller lakes in Madelia, within a few miles to the southeast from Emerson lake; a dozen smaller lakes, probably some of them dry in the summer, lying in Fielden and Antrim; three lakes in Saint James, the largest, a mile or more in length, close southwest of the town; Long lake, two and a half miles long from east to west and half a mile wide, and Kansas lake, of equal width and a mile in length, in Long Lake township; four unnamed lakes in Odin, the largest, in sections 5 and 6, being about a mile long and a half mile wide; and Wood lake in Adrian, two and a half miles long and from a quarter to a half of a mile wide.

The greater part of Martin county is also included within the basin of the Blue Earth river, to which its waters are carried by Elm, Center and South creeks, all of which join the Blue Earth in Verona, Faribault county. Elm creek, the largest of these, and the only one which rises beyond the west line of this county, has been sometimes called Chain river; deriving its name from the remarkable chains of lakes which find their outlets by these creeks. The southeast corner of Martin county is tributary to the Blue Earth river by smaller creeks above the foregoing; and the north edge of the county sends its streams to the Watonwan river.

An area of about a hundred and fifty square miles in the southwest part of Martin county lies in the basin of the Des Moines and is drained by the head-stream of the East fork of this river, which has its farthest source nearly at the middle of the line between this and Jackson county and thence flows southeastward, passing through Tuttle's lake upon the state line.

The *lakes* of this county, mostly lying in three distinct chains or series, present very interesting features, and seem to give important evidence respecting the history of the glacial period. On this account further notice of them is deferred to the later part of this chapter where the drift is described.

Topography. Watonwan county descends toward the east and northeast, but in a broad view its slightly undulating expanse seems nearly level. Generally its surface is in very gentle slopes which soon conduct the surplus waters of rains and snow-melting into depressions, which merge into ravines and lead to small water-courses, and by them to the larger permanent streams. Here and there, however, are depressions which have no such free drainage, and contain sloughs or lakes.

The general slope of Martin county sinks slightly toward the east, giving direction to its streams. To the traveler this descent is imperceptible, and it appears as a vast, moderately undulating, but approximately level prairie. Erosion by the present creeks of this county has depressed them from ten to thirty or forty feet below the average hight of the land on each side, forming along considerable portions of their course distinct valleys, with irregularly sloping, narrow bottomlands, bordered by low but steep bluffs. In Watonwan county the South fork of the Watonwan river lies in a valley which it has cut forty feet below the general level along all its course from Mountain Lake to Madelia; and the North fork and its tributaries have similarly channeled their part of the drift-sheet. Below the junction of these branches the Watonwan valley increases to fifty or sixty feet in depth before leaving the county at the southeast corner of Madelia. The only place at which these valleys have cut through the drift is in Martin county, on Elm creek in section 6, Rutland, where the bed-rock, probably sandstone, is found at a slight depth below the surface.

Adrian, the most northwest township of Watonwan county, has the only outcrop of the bed-rock in these counties, this being the eastern extremity of a prominent ridge of the red Potsdam quartzyte. It is seen at the surface in the N. W. ¼ of section 29, and gives to this and the contiguous sections 30 and 19 an elevation fifty to one hundred feet above the rest of this township; but this ridge here, and through its whole extent of nearly twenty-five miles westward, where it rises much higher, is mainly covered by a smooth sheet of till.

Elevations, St. Paul & Sioux City division, Chicago, St. Paul, Minneapolis & Omaha railway.
Copied from profiles in the office of T. P. Gere, superintendent, St. Paul.

	Miles from St. Paul.	Feet above the sea.
Madelia	109.0	1021
Watonwan river, water	110.5	979
Lincoln	116.4	1042
Saint James	121.6	1073
Butterfield	130.1	1184

Elevations, Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.
From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Winnebago City (Faribault county)	166.3	1096
Fairmont	183.0	1176
Sherburne	197.5	1273
Junction of branch to Jackson depot (Jackson county)	209.1	1446

The highest land of Watonwan county is either the east part of the quartzyte ridge in sections 19 and 30, Adrian, or the southwest corner of the county, both of which are nearly 1,300 feet above the sea. Its lowest land is where the Watonwan river passes out from this into Blue Earth county, at a hight of about 960 feet above the sea. The mean hights of the townships of this county are approximately as follows: Madelia, 1,025 feet above the sea; Fielden, 1,050; Antrim, 1,100; River Dale, 1,040; Rosendale, 1,060; South Branch, 1,120; Nelson, 1,075; Saint James, 1,120; Long Lake, 1,150; Adrian, 1,150; Butterfield, 1,200; and Odin, 1,240. From these estimates the mean elevation of Watonwan county is found to be 1,110 feet, very nearly, above the sea.

In Martin county the greatest altitude is attained at the west side of Lake Fremont township, about 1,400 feet above the sea; and the lowest points of this county are at its east line where Elm, Center and South creeks are 1,050 to 1,075 feet in elevation. The townships of this county, with their mean hights approximately estimated, are: Nashville, 1,125 feet above the sea; Center Creek, 1,140; Pleasant Prairie, 1,200; East Chain, 1,240; Westford, 1,150; Rutland, 1,175; Fairmont, 1,200; Silver Lake, 1,230; Waverly, 1,175; Frazer, 1,200; Rolling Green, 1,240; Tenhassen, 1,250; Galena, 1,200; Fox Lake, 1,240; Manyaska, 1,260; Lake Belt, 1,275; Cedar, 1,260; Elm Creek, 1,300; Jay, 1,325; and Lake Fremont, 1,350. The mean elevation of Martin county, deduced from these figures, is 1,225 feet.

Soil and timber. The soil of Watonwan and Martin counties, like that of a vast region extending from them on all sides, is very fertile, easily worked, and well adapted for the cultivation of all the staple agricultural products of this latitude. A black, clayey, and slightly sandy and gravelly loam, from one to three feet thick, forms the surface, which is nearly everywhere sufficiently undulating to carry away the waters of heavy rains and snow-melting. Boulders are scattered very sparingly over the entire area of these counties, but scarcely anywhere are objectionably numerous. This soil and the subsoil of yellowish gravelly clay are the till, or unmodified drift of the glacial period. They are somewhat porous on account of their considerable proportion of sand intermixed, causing them to absorb much moisture from rains and give it up readily to vegetation. The principal crop of Watonwan county, as generally northward through this state, is

wheat; but in Martin county corn, stock, and dairying also hold a prominent place, as commonly southward through Iowa.

Both these counties are principally prairie, being natural grassland, without tree or shrub; excepting narrow skirts of timber, which generally surround the lakes and extend along the principal streams, sometimes widening to form groves. Probably the aggregate area of these belts of timber is less than one hundredth part of either Watonwan or Martin county. The following species of trees, arranged in their estimated order of abundance, were noted as occurring on the South fork of the Watonwan river: American or white elm, white ash, box-elder, ironwood, cottonwood, bur oak, slippery or red elm, hackberry, bass, soft maple, black walnut, willows, the American aspen or poplar, and the wild plum. Common species of trees about Silver and Iowa lakes, in Martin county, are bur oak, bass, white ash, white and red elm, and black walnut; bitternut is somewhat frequent; and cottonwood, soft maple and butternut occur rarely.

GEOLOGICAL STRUCTURE.

The only exposure of bed-rock in Watonwan county is found, as already stated, in the N. W. $\frac{1}{4}$ of section 29, Adrian. A smooth and flat surface of the very compact and hard, red Potsdam quartzyte is seen here along an extent of five rods from northwest to southeast, with a width varying from five to twenty feet. This is on an eastward slope, in a slight depression of drainage. The quartzyte does not project out of the drift, and cannot be seen at a distance. It is undoubtedly the bed-rock beneath all the southwest quarter of Adrian, but is elsewhere covered within the limits of this township and county by the smoothed sheet of glacial drift, which rises in a broadly rounded ridge because of the prominence of this underlying rock. Through the north half of section 30, Adrian, it lies at no great depth, and has been encountered in ploughing and digging at several places. This ridge, having here and there outcrops of the same red quartzyte, continues more than twenty miles to the west, in northern Cottonwood county.

In Martin county a large mass of compact, gray sandstone, contained in the till, has been quarried at the south side of Elm creek in the west part of section 6, Rutland, on land of G. S. Livermore of Fairmont, yielding

Cretaceous sandstone.]

about three cords of good building stone, besides one or two cords of inferior quality wasted. This lay at a hight of about five feet above the creek, being imbedded in the base of its bluff of till, which rises thirty feet. It was divided in beds one to two feet thick, with an inclination of about 30° eastward, and is said to have been entirely removed by quarrying. Some of these layers show oblique lamination. The color and texture of this stone, its rarely enclosing soft black particles, which are apparently lignite, and the oölitic structure that much of it exhibits, give it a very close resemblance to the sandstone, quite surely of Cretaceous age, found outcropping in Alta Vista, the most northeast township of Lincoln county, and in Eidsvold and Westerheim, lying next to the east in northwestern Lyon county. Mr. Livermore states that bed-rock exists near the surface, as learned by thrusting down an iron bar, along the marshy bottomland and beneath the channel of the creek, for a distance of six or eight rods from the point where this block occurred, being probably the same formation in place, but not rising into view. The only wells learned of in these counties that have gone through the drift are the following, situated in Fairmont and Jay townships in Martin county.

On land of A. L. Ward, in section 9, Fairmont, a well about 150 feet deep went through drift, 90 feet; hard rock, about 50 feet; and a softer layer 10 feet thick, from which water rose to sixty feet below the surface. On land of H. W. Sinclair, in section 29, Fairmont, rock was encountered at a considerable depth and the well was abandoned. No further details were ascertained respecting the bed-rocks in these wells; consequently no opinion of their geological age can be given. The strike of the limestone and sandstone formations of the Lower Magnesian series, in their exposures along the valley of the Minnesota river and in Blue Earth county, indicates that their continuation underlies the greater part of Watonwan and Martin counties; but here they are doubtless covered in part and perhaps mainly, by Cretaceous strata.

Deposits which seem referable to the Cretaceous age, were found in the lowest thirty feet or more of a well 180 feet deep, on the farm of Cargill, Van & Co., in the S. E. ¼ of section 14, Jay. This was dug a hundred feet and bored below. Its section in the portion dug was soil, 2 feet; yellow till, 18 feet; and very hard blue till, much of it about as hard to excavate as rock, 80 feet. Some ten barrels of water come in daily from the lower two feet of the yellow till, but none was found in the blue till. The portion bored consisted of yellowish gray sand with little gravel, dry, and yielding gas in which fire could not burn, 50 feet; then, shale, 10 feet; and gray sand or soft sandstone, bored into 20 feet, and continuing below the bottom of the well. The last thirty feet were bored during the rainy season, when so much water (a hundred barrels or more per day) came in from the yellow till that it was not evident whether the last stratum yielded any water. This well was made in 1879 and the spring of 1880, and supplies all the water that is wanted from it. The strata here encountered below 150 feet probably belong to the Cretaceous age, and perhaps also the fifty feet of sand between these and the till. This thick bed of gas-bearing sand and gravel was struck at the bottom of a well 113 feet deep at Sherburne station, two miles to the northeast, of which full notes are given in the list of wells illustrating the drift.

Drift and contour.

Glacial striæ are very distinct on the quartzyte ledge exposed in section 29, Adrian, mostly bearing S. 30° E., referred to the true meridian, but in one place, on its southeast portion, bearing S. 20° E.

The contour of Watonwan and Martin counties is like that which prevails generally in the basin of the Minnesota river, and is formed by a slightly undulating or in some portions moderately rolling sheet of till, with massive swells rising in long smooth slopes ten to twenty or thirty feet above the depressions. The gently undulating, smoothed surface of most of this region appears to mark areas over which the ice-sheet moved in a continuous current, and from which it disappeared by melting that was extended at the same time over a wide field. Compared with the thickness of the drift, its inequalities of contour in these counties are small, and in an extensive view it seems approximately flat. It is a part of the inclined plain which rises by an imperceptible slope from the Minnesota river to the Coteau des Prairies. Its rate of ascent toward the southwest, or increase in average hight, varies from five to fifteen or twenty feet per mile. This gradual change in altitude is doubtless produced by increase in hight of the bed-rocks upon which the drift lies as a sheet of somewhat uniform depth, probably varying in these counties from 50 to 150 feet; but the numerous small elevations and depressions of the surface appear to be due to the accumulation of different amounts of till by adjoining portions of the moving ice-sheet, without any corresponding unevenness of the underlying rocks.

Third terminal moraine. The most rolling portion of the drift-sheet in these counties is at the southeast, entering East Chain township from Iowa, and reaching northwestward to Fairmont. It is the continuation of a belt of hilly till, which is connected with the inner or western one of the two terminal moraines that extend from north to south through northern Iowa, passing near Clear Lake and Forest City. This belt, three to six miles or more in width, reaches from the vicinity of Pilot mound in northeastern Hancock county northwestward about forty miles, by Forest City, through western Winnebago county and northeastern Kossuth county in Iowa, and into southeastern Martin county. It attains its greatest hight in the north part of township **98**, range **25**, Winnebago county, where it is 100 feet

Third terminal moraine.]

above the general level. In northeastern Kossuth county this tract expands to a width of ten miles and reaches from Ramsey, at the east side of Union slough, north and northwest to the state line, lying on both sides of the head-stream of the Blue Earth river. Its northeast border is in the south edge of Elmore and Pilot Grove in southwestern Faribault county, where it consists of hillocks and short east-to-west ridges of till, 30 to 50 feet high. Thence these accumulations of till occur scatteringly in southeastern Martin county to East Chain and less prominently to Fairmont. In these townships the contour is seldom rough, but rises in swells 25 to 50 feet above intervening depressions, with trends more frequently from northwest to southeast than in other directions; while nearly all the remainder of this county is more smoothly undulating, in longer slopes, with the highest parts only 10 to 20 feet above the lowest near.

The belt of hilly and rolling glacial drift thus traced from Iowa into Minnesota was probably accumulated as a terminal moraine at the end of the ice-lobe which extended southeastward from the Leaf hills and the Head of the Coteau des Prairies, as more fully explained on page 406; but at a late part of the epoch, after two distinct recessions of the ice had taken place in southwestern Minnesota. When this lobe of the ice-sheet attained its greatest area it terminated on the south in the vicinity of Des Moines, and was bounded on its sides by the outermost belt of hilly and knolly drift deposits. On its east side only two morainic belts are found, but on its west side three are clearly distinguished in the west edge of this state and the east edge of Dakota.* At the time of accumulation of the second belt of morainic drift, the end of this ice-lobe had receded to Mineral ridge in the north part of Boone county, Iowa; and when the third belt was formed, its extremity appears to have been in Hancock county, Iowa. The length of this ice-lobe was thus diminished forty miles between the times of formation of its first or outer moraine and its second or inner moraine, and was still further shortened seventy-five miles before its third moraine was accumulated. Across the area from Fairmont northwest to Yellow Medicine county this third moraine was not noticed as a continuous formation. In the line where it would be looked for, we find the surface somewhat more prominently rolling than ordinary in Waverly, at the north side of Martin county; but only the usual low undulations were noted northwestward in Watonwan county. The nearest tract of typically morainic contour observed in this direction, which seems to be probably a part of this belt, is thirty miles from Waverly in the north part of Stately, the most southwestern township of Brown county.†

For one or two miles southeast and south of Madelia, and for one mile southeast of Saint James, the surface has frequent swells twenty to thirty feet above the depressions, being more rolliug than most other parts of Watonwan county, which is generally very gently undulating in smooth prolonged slopes, with occasional lakes and here and there sloughs ten to twenty feet below the highest portions of the adjoining country.

Chains of lakes. It has been frequently noted that the lakes which abound upon areas overspread by the glacial drift, have their prevailing trend, or average direction of their longer axes, parallel with the course

*See the ninth annual report.

†During the examination of these counties, and of others northwestward, where this moraine may very likely be found traceable continuously, though not conspicuous excepting a few portions described in the following chapters, to the third terminal moraine in Yellow Medicine and Lac qui Parle counties, this highly probable relationship was not recognized, and the writer owes the suggestion of it to Prof. T. C. Chamberlin. It seems desirable that this region be traversed again, with the special object of tracing this moraine. (Also see page 463.)

that was taken by the ice-sheet. The swells and undulations of the till have their greatest extent in this direction, and the lakes fill the hollows that are formed by its unequal accumulation. Among the hills of the terminal moraines, however, the longer axes of the lakes are apt to be transverse to the course in which the ice came, but parallel with its border. In each case, such lakes are due to variable glacial erosion and deposition; and the basins in which they lie are not more remarkable features of the contour than are its swells, hills, and areas of highland. The deepest lakes contained in depressions of the till in this state are from fifty to one hundred and fifty feet in depth, reaching as far below the average level of the drift-sheet as its most elevated portions rise higher; but a great majority of these lakes, especially upon regions of only slightly undulating surface without prominent elevations, are shallow, ranging from five to twenty-five feet in depth. They mainly have very gently ascending shores, but sometimes on one or more sides are partially bounded by steep banks five to twenty or thirty feet high, formed by the wear of waves which have eaten away projecting portions of their margin of till, leaving its boulders, but strowing its finer detritus over the lake-bed.

In regions of modified drift, consisting of stratified gravel and sand that were supplied from the dissolving ice-sheet, the lakes, from ten to fifty feet or more in depth, and often bordered by level or undulating tracts of modified drift, from twenty-five to one hundred feet or more above them, lie in depressions which at the time of the fluvial deposition of this drift were probably still occupied by unmelted masses of ice, preventing sedimentation where they lay and consequently leaving hollows enclosed by steep and high banks, whose top is the margin of plateaus or plains of gravel and sand. No examples of lake basins thus surrounded by modified drift were found in Watonwan and Martin counties, neither of which have any noteworthy deposits of this class, nor any such rough morainic areas as to influence the distribution and trend of their lakes.

Most of the lakes of Minnesota, and of all glaciated regions, present only such forms and arrangement as are readily explained thus by the modes of excavation and accumulation, and the diverse deposits of the ice-sheets. The first described and most common type of lakes found upon the surface of the drift, trending in parallelism with the course in which

the ice moved, finds illustration in Watonwan county by the lakes of Madelia, Fielden, Long Lake and Adrian. Here the glacial current passed southeastward, this region being near the axis of the great lobe of the continental glacier which stretched from the Leaf hills and the Head of the Coteau des Prairies southeast and then south to the center of Iowa.

Martin county presents, however, in its three remarkable chains or series of lakes, a problem which the foregoing general explanations of the origin of lakes upon areas of glacial drift do not solve, though they are needed to prepare us for its consideration. These series are known as the East, Central and West chains of lakes.

South creek receives the outflow from the East chain of lakes, and connects them by a stream which descends toward the north. This chain extends from the Iowa line about twelve miles northerly in a somewhat irregular course, lying upon the line between East Chain and Silver Lake townships, and continuing northward through the east part of Fairmont and the northwest corner of Pleasant Prairie. It includes two lakes in section 36, Silver Lake; two lakes at the west side of sections 19 and 18, East Chain, now united under the name of East Chain lake by a dam which has a fall or head of eight feet; two unnamed lakes in sections 7 and 6, East Chain; another, about a mile long, lying principally in section 36, Fairmont; Rose lake, a mile and a half long from south to north, at the west side of sections 25 and 24, Fairmont; lake Imogene, on the township line, about one and a half miles northeast from the last; and Lone Tree lake, lying a mile farther northeast and reaching about a mile in length from south to north, at the east side of section 6, Pleasant Prairie, and of section 31, Center Creek. These lakes are bordered by rolling areas of till, thirty to forty feet above them, to which elevation their shores ascend mostly by quite steep slopes. The east bank of East Chain lake, two miles in length, has been recently undermined along the greater part of the first mile from its north end. In width the lakes of this chain vary from one-fourth to two-thirds of a mile. The spaces between them are sometimes marsh and as wide as the narrower parts of the lakes, but in some other portions is a contracted channel, such as might have been cut by the stream which outflows from them. Thus the series does not occupy depressions in any well-marked continuous valley. Another lake lies close beside this series in section 12, of Silver Lake township, but divided from it by a portion of the till thirty to forty feet high, through which it has no outlet. The fall of South creek through this chain of lakes in the distance of about nine miles from the Iowa line to the mouth of Rose lake, whence it turns northeastward, is about fifteen feet, half of this being at the East Chain dam.

The Central chain includes about twenty lakes, and extends twenty-two miles in almost perfectly straight due north course from Iowa lake, crossed by the state line, to Perch lake at the head of Perch creek, three miles south of the line of Watonwan county. This series of lakes lies three to six miles west of the East chain, being in the west part of Silver lake, Fairmont, Rutland and Westford, which form range **30** in this county. Their outlets are South, Center, Elm and Perch creeks. In their order from south to north, the lakes of this Central chain are Iowa lake, two and a half miles long from northwest to southeast, and from a quarter of a mile to one mile wide; Silver lake, close north of the last, one mile long and a half mile wide, lying at the east side of section 30 of the township to which it gives its name; Summit lake, beginning about an eighth of a mile north of the last, and extending a mile at the east side of section 19; Wilmont lake, a mile long and two-thirds of a mile wide, lying mostly in section 7; Bardwell lake, beginning about three-fourths of a mile north of the last and reaching thence a mile to the north with a width of about a quarter of a mile, mostly in section 31, Fairmont; Mud lake, of small size; Amber lake, shorter but wider than Bardwell lake, in the east part of section 30; Hall's lake, mostly in sections 19 and 20, one and a quarter miles long from south to north and from a half to three-fourths of a mile wide; Budd's lake, extending about a half mile in both length and

width, crossed by the line between sections 17 and 18; lake Sisseton, nearly a mile long, at the west side of the town of Fairmont; Lake George, three-quarters of a mile long, at the east side of section 6; Buffalo lake, at the east side of sections 31 and 30, Rutland; the Twin lakes, about a mile farther north; lake Charlotte, in section 17, Rutland; High lake, at the southeast corner of section 7; Martin lake, a mile long from south to north and a third of a mile wide, lying on the line between sections 5 and 6, Rutland; a lake, nearly a mile long, at the east side of sections 31 and 30, Westford; and Perch lake, in sections 19 and 18 of this township.

The shores and the country on both sides of the Central chain of lakes, as of the East chain, consist of till, which soon rises to a moderately undulating expanse that has a hight thirty to forty or fifty feet above the lakes. Though forming a very distinct, straight series, they do not occupy a well-marked continuous valley; but its width varies from one mile or more to less than an eighth of a mile, and it is in three places interrupted by water-divides at whose lowest points the slopes of till reach ten to fifteen feet above the adjoining lakes. Silver and Iowa lakes are the headwaters of South creek, and have their outlet by a stream that runs east nearly along the state line to the south end of the East chain. The middle part of the Central chain, reaching twelve miles from Summit lake to the Twin lakes is tributary to Center creek; and its portion farther north, excepting Perch lake, is within the belt drained by Elm creek.

Iowa and Silver lakes have the same level, which is nearly that of Summit lake. Mr. William H. Budd, of Fairmont, states that the descent from Summit lake to Wilmont lake is three feet; thence to Bardwell lake, probably ten feet; thence to Mud and Amber lakes, still water; thence to Hall's lake, about two feet; to Budd's lake, again about two feet; to lake Sisseton, one foot; and to lake George, one and a half feet. Buffalo lake and the Twin lakes, lying north of Center creek, and lake Charlotte, tributary to Elm creek, are reported by Mr. Budd to be at about the same level with lake George, being some six feet higher than Center creek at a half mile farther east, and about twenty feet below Summit, Silver, and Iowa lakes at the southern end of this chain. From lake Charlotte to Martin lake, the fall is about two feet, and the remaining lakes of the series, north of Elm creek, have approximately the same hight.

East Chain lake, though raised by its dam, has a depth of only fifteen feet, and probably none of the lakes of that chain are much deeper. The maximum depths of some of the lakes in the Central chain are reported as follows: Iowa lake, fifteen feet; Silver lake, about fifty feet, being the deepest of this series, as none of its other lakes, and perhaps no other in this county, exceeds half this depth; Hall's lake, twenty or twenty-five feet; Budd's lake, sixteen feet; and lake Sisseton, eight feet.

The West chain of lakes is less distinctly connected than the East and Central series, from which it also differs in having the longer axes of some of its lakes transverse to the course of the chain, and in having shorter series of lakes joined with it as branches. Its south end is Tuttle's lake, which is crossed by the state line, about four miles west of Iowa lake, the south end of the Central chain. Thence the West chain reaches northwesterly twenty miles, then northerly nine miles, and then northwest and west eight miles, to Mountain lake in Cottonwood county, its whole extent being thirty-seven miles. From the middle of the south line of Martin county, it extends through the townships of Tenhassen, Lake Belt, Manyaska, Fox Lake, Elm Creek and Cedar, in this county, crossing its north line five miles from its northwest corner; through Odin, the most southwest township of Watonwan county; and into Mountain Lake township in Cottonwood county. It is tributary, in its successive portions from south to north, to the East fork of the Des Moines river, to Center and Elm creeks, and to the South fork of Watonwan river. This West chain comprises about twenty-five lakes, in the following order from south to north: Tuttle's lake, on the state line, about four miles long from northeast to southwest and averaging a mile in width, reaching in Martin county from the south side of section 31 to the north side of section 28, Tenhassen; Alton lake, one and a half miles long and one-fourth to two-thirds of a mile wide, in sections 20, 19 and 18, of this township; Dutton or Swan lake, Clear, Fish and Buffalo lakes, each nearly a mile long, and together stretching west-northwest four miles, from near the northeast corner of section 25 to the northwest corner of section 21, Lake Belt, which takes its name from these four lakes; Holmes lake, at the north side of sections 2 and 3, and Goose lake, lying mostly in section 4 of the same township, each about one and a half miles long, trending from east to west and southwest; Prairie lake, in sections 15, 22 and 21, and Manyaska lake, in sections 20 and 19,

Chains of lakes.

Manyaska, similar to the last in their extent and trend; Munger lake, in sections 17 and 8, about a mile long from south to north; Temperance lake, close north of the last, of similar length, but trending from southwest to northeast; Fox lake, three and a half miles long from east to west, and from a fourth to a half of a mile in width, lying at the south side of sections 31, 32 and 33, of Fox Lake township; an unnamed lake, a mile long from east to west and half a mile wide, mostly in section 31, north of the west end of Fox lake; the Big Twin lakes, together extending two and a half miles from southeast to northwest, in sections 13, 12, 11 and 2, Elm Creek; Cedar lake, about three miles long from south to north, with an average width of a half mile, lying mainly in sections 36, 25 and 24, Cedar; three other lakes, each about a mile long, in sections 13, 12 and 1, Cedar; three unnamed lakes, varying from a half to three-fourths of a mile in length, and all trending from southeast to northwest, situated in Odin, Watonwan county, the first being mainly in the north half of section 26, the second in the west part of section 15, and the third extending through the northwest corner of section 10; a lake, one mile long from east to west and a half mile wide, in sections 5 and 6; a small lake at the northwest corner of section 6, Odin; and Mountain lake, two miles long from northeast to southwest and nearly a mile wide, situated two miles southeast from Mountain Lake depot and village.

The series of four lakes mentioned in Lake Belt township, lies somewhat west of the direct course of this chain of lakes, and may be regarded as a branch of it; and two miles east of this lake-belt, another series of lakes, very plainly a branch of the West chain, diverges from it, and reaches almost due north twelve miles from Tuttle's and Alton lakes. This series, connected at its south end with the West chain, includes in order from south to north, Clayton lake, a mile or more in extent, lying mostly in sections 21 and 16, Tenhassen; Babcock lake, about a mile long from southwest to northeast and more than half as wide, in sections 17, 8 and 9, and Rice lake, three-quarters of a mile long, at the west side of section 4 of the same township; Pierce lake, about a mile in diameter, in sections 27 and 28, and a long and narrow lake, reaching from section 10 to section 7, in Rolling Green; Swan lake, a half mile long, in section 31, Fraser; and Eagle lake, close northeast of the last, covering nearly all of section 29 and portions of the adjoining sections, two miles in length, with trend from northwest to southeast. To these, as a continuation of this branch, ought perhaps to be added four other lakes, which are situated four to nine miles farther north, varying from a half mile to one mile in length, and principally included in sections 36 and 25, Galena, and sections 18 and 7, Waverly.

Besides the lakes thus enumerated as constituting the three chains of lakes and this branch series, which lies midway between the Central and West chains and is connected with the latter, Martin county has only three other lakes of noteworthy size, namely, Ash and Calkins lakes, each about one and a quarter miles long, in the south part of East Chain township; and another of similar extent, in sections 16, 9 and 8, Elm Creek.

The West chain of lakes, like the East and Central chains, extends through a region of moderately undulating till, the direct deposit of the ice-sheet, with no noteworthy areas, nor unusually thick included layers, of water-deposited gravel and sand. The lakes of the south half of this western series, and of its branch from Tuttle's to Eagle lake, lie only ten to twenty feet below the average hight of the adjoining land, which rises in long, gentle slopes from their shores. Northward, in Cedar, Odin and Mountain Lake townships, the contour is nearly like that along the East and Central chains, the lakes being bordered by bluffs of till, of moderate or often steep ascent, thirty to forty feet high, whose crest is at the general level of the slightly undulating drift-sheet. In Mountain lake an island, which has given this name, rises with steep shores and table-like top, about forty feet above the lake, having similar outlines with the surrounding bluffs and upland. Much of this lake is now filled with grass and reeds.

It seems difficult to explain the origin of these remarkable lake-basins in the drift, for, so far as they extend, they have the aspect of eroded valleys, such as have been commonly formed by the rivers of this region, but they sometimes are separated by divides of till as high as the country around. Thus they no longer form continuous channels, which must have

been their original condition, if they are parts, as thus indicated, of ancient water-courses. Nowhere else in my exploration of the glacial drift, have similar chains of lakes been found, bordered and occasionally divided by areas of till, without notable deposits of modified drift, and not occupying distinct valleys of former streams. Yet these plainly connected series of lakes, converging, and one of them receiving a tributary branch, in their course toward the south, are related to each other like confluent rivers. Their origin cannot be referred to the ordinary causes and conditions, already reviewed, which produced the irregularly scattered lakes of drift-covered areas; but, excepting this arrangement of its lakes, Martin county is not distinguishable from the surrounding region of drift.

The explanation of these series of lakes, which seems most probable, is that they mark interglacial avenues of drainage, occupying portions of valleys that were excavated in the till after ice had long covered this region and had deposited most of the drift-sheet, but before the last glacial epoch, which again enveloped this area beneath a lobe of the continental glacier, partially filling these valleys, and leaving along their courses the present chains of lakes. Fossiliferous beds are occasionally found in this and adoining states, and, significantly, at a few places within the basin of lake Agassiz, intercalated between thick deposits of till. Some of these interglacial beds, doubtless including those in the Red river valley, since covered by lake Agassiz, were formed after an ice-sheet had extended to the extreme southern limit of the glacial drift. They prove that the long, very severely cold period in which ice-fields reached south to northeastern Kansas, St. Louis, and southern Illinois, was succeeded by a milder climate, under which the ice was melted from Minnesota and even as far northward as to Hudson bay, again permitting plants and animals to occupy the land. The terminal moraines of the Northwest, formed by a later ice-sheet, show that another great epoch of cold once more buried the north half of the continent under ice, which, however, did not extend so far south as before. This ice was divided at its border into vast lobes, one of which, about three hundred miles long and one hundred miles wide, and probably from a tenth to a half of a mile thick, was accumulated upon the area that stretches from the head of the Minnesota river southward to central Iowa, including Watonwan and Martin counties, its width at this latitude being from

Chains of lakes.]

Albert Lea on the east to Worthington on the west. Before the glacial epoch in which the ice had its greatest extent, and probably also between that time and the date of the terminal moraines that cross Wisconsin, Minnesota and Dakota, other glacial epochs spread ice-sheets upon this region; but their moraines have been leveled and covered with additional deposits of till, and the interglacial soil and fossiliferous sediments of sloughs and lakes have been mostly ploughed up and mixed in the drift, while their remnants have been similarly buried, by the more extended ice-sheets of these subsequent epochs. Such remnants of interglacial beds, containing leaves and shells, have been found in Center Creek and Silver Lake townships in Martin county, as stated in the notes of wells on page 487. The chains of lakes in this county appear to show that interglacial rivers, between the time of greatest extent of the ice and the date of the last glacial epoch, were here carried southward in four confluent valleys to the East fork of the Des Moines river. The present drainage of Martin county is mostly transverse to this course and tributary to the Blue Earth river; but the watershed and slopes that now turn it away from the Des Moines are so slight that if the streams of this area had channels from north to south, such as were probably eroded along the lines of these chains of lakes while the margin of the ice-sheet that had reached to the farthest limit of the glacial drift was receding across these counties, they would continue to flow southward to the Des Moines. Probably all of this county, excepting perhaps its most northeast township, was during a long interglacial epoch included within the Des Moines basin, which still embraces a part of it at the southwest. The last ice-sheet doubtless added considerably to the drift, but did not entirely remold its topographic features; so that here even the interglacial water-courses cut in the drift remain in some portions with little change, still having steep bluffs and holding these series of lakes. This interpretation of their meaning is strongly confirmed by features of the valley of the Minnesota river, which seem to be explicable only by referring them to similar causes.*

Boulders and gravel, though always present, are nowhere abundant in the till of Watonwan and Martin counties; and boulders larger than five feet in diameter are very rare. The frequency of limestone fragments is nearly the same as is usual through all western Minnesota. This rock often makes one-third or one-half of the gravel in the till and on the beaches of lakes; but it supplies a much less proportion, perhaps not exceeding one twentieth, of the boulders larger than

*Compare article on the Minnesota valley in the ice age, *Proc. o Amer. Assoc. for Adv. of Science*, 1883, and *Amer. Jour. Sci.* (3), vol. xxvii, 1884.

a foot in diameter. The other large boulders are granite, syenite, and crystalline schists. The red Potsdam quartzyte is scantily represented in the drift along the west border of these counties. It is almost entirely wanting farther east; but west of the Des Moines river, in Jackson county, and through Dickinson county and southward in Iowa, this quartzyte is a principal ingredient of the drift, making from one tenth to one half of its rock-fragments. At Clear lake in Lake Belt township, thirty-five miles south-southeast from the east end of the ridge of Potsdam quartzyte in Adrian, scarcely one pebble in a thousand is from this source: while a quarter of the stones over three inches in diameter, and two-thirds of the smaller gravel, are limestone.

Wells in Watonwan county.

Madelia. H. B. Wadsworth; Madelia village: well, 50 feet deep; soil, 2 feet; yellow till, spaded, 28 feet; much harder blue till, 20 feet; water rose ten feet in two hours from gravel at the bottom. Most of the wells at Madelia are from 15 to 30 feet deep, having a good supply of water that seeps from the yellow till. Lignite, in fragments up to three or four inches long, and small pieces of wood, as of twigs or limbs, are occasionally found embedded in the till of these wells. Their water is invariably good, except in occasional instances where it has been spoiled by the decay of wooden curbing.

Fielden. H. W. Wadsworth; sec. 21: well, 70 feet; soil, 2; yellow till, spaded, 25, with water seeping sparingly in its last three or four feet; much harder blue till, picked, 43; water rose forty feet in three hours from whitish gravel at the bottom. Several pieces of lignite were found in the upper till. Wells in this township often find an ample supply of water at a depth of 25 feet or less. The only flowing well learned of in this county is William Sargent's, on section 20, about 25 feet deep.

Antrim. C. O. Martin; sec. 8: well, 29 feet; soil, 2; yellow till, 23; blue till, 4; water rose twelve feet in one day from gravel and sand at the bottom.

Robert Dewar; sec. 10: well, 70 feet; soil, 2; yellow till, spaded, 25; sand and gravel, with clay, interstratified, 4 feet; blue till, harder than the upper till, yet much of it spaded, 39 feet, the lowest two or three feet very hard; at the bottom, water rose from gravel and sand twenty-five feet in a half day.

South Branch. Benjamin A. Town; sec. 14: well, 23 feet; soil, 2; sandy yellow till, with water in its lower part, 5 feet; moist blue till, mostly spaded, 16 feet; water rose six feet in one day from a gravelly streak in the blue till.

Long Lake. William Evans; sec. 19: well, 21 feet; soil, 2; yellow till, picked, 19; water comes slowly from sandy streaks at the bottom.

Saint James. The railroad well here was dug 22 feet, and then bored about 10 feet more, through blue till, to white sand, from which 1500 barrels of water have been drawn in ten hours.

G. H. Reynolds; Saint James: well, 28 feet; all yellow and blue till; water came up unexpectedly at night, when the workmen had left the well dry the previous afternoon, filling the well to two feet below its top. The yellow till at this town is 10 to 20 feet deep, with blue till usually a little softer, below.

John Schutz; sec. 10: well, 28; soil, 2; yellow till, 10; blue till, 16; water rose ten feet in one hour.

James Curry; sec. 18: well, 25; soil, 2; yellow till, spaded, 20; sand and gravel, with water, 1 foot; blue till, softer than the yellow, 2 feet. It was estimated that a half bushel of fragments of lignite, up to six inches in length, was found in the till here; but none was contained in the sand and gravel.

Adrian. Joel Parker; sec. 26: well, 22; soil, 3; yellow till, spaded, 20; with softer and moister blue till below; water seeps in the lower part of the yellow till.

Frederick Klein; S. W. ¼ of sec. 30: well, 27; soil, 2; yellow till, 10; softer and moister blue till, 13; gravel and sand, 2 feet, and extending deeper; water rose two or three feet above the top of the gravel; lignite was found in fragments up to three inches long. The water in all the wells of this region is of excellent quality.

Wells in Martin county.

Nashville. Henry C. Henton; sec. 9: well, 24 feet deep; soil, 2 feet; yellow till, 19 feet; gravel, 3 feet, and reaching below; water rose fourteen feet in one hour.

J. A. Armstrong; S. E. ¼ of sec. 9: well, 81 feet; soil, 2; yellow till, 22; gravel and sand, 6 inches, yielding enough water for ordinary house use; blue till, very compact, but moist and soft to bore, 56½ feet; the auger then dropped, and within fifteen minutes the water rose through thirty-one feet of two-inch boring so fast as to fill in this time thirty feet of the larger boring above, three feet in diameter, rising thus sixty-one feet. Within a distance of six rods around this place, six wells have found quicksand at a depth varying from 12 to 16 feet, thence extending, at least in some of these wells, to a depth of five or six feet, but not passed through by any of them, because of its immense supply of water. These shallow wells, however, were unserviceable from becoming filled with quicksand.

J. H. Smith, in sec. 3 of this township, has a well about 75 feet deep, which has several times become filled nearly to the top with quicksand.

Most of the wells in northeastern Martin county are only 10 to 30 feet deep, finding plenty of water in the lower part of the yellow till, or in gravel and sand under this and overlying the blue till. Lignite is occasionally found, the largest fragments being three or four inches long.

Center Creek. Hosea True's well, in the north part of this township, is reported to have been till, 60 feet, yellowish near the surface and dark bluish below; then sand 8 feet, containing "elm leaves and clam shells in abundance, the latter three to four inches long." This is on the ordinary undulating surface of the drift-sheet, south of the valley of Elm creek. Mr. Alexander Douglas, who bored this well and reported it thus, states that in his work boring nearly forty other wells in this county, he nowhere else found leaves, but in several instances found similar shells in coarse dark sand, at depths varying from 20 to 60 feet below the surface, under yellow and then blue till.

Westford. E. Huber, sec. 34: well, 45 feet; soil, 2; yellow till, 10; blue till, softer, moist and tenaceous, most gravelly in its lower part, 33 feet; water, seeping from the lower part of the blue till, filled this well to a depth of ten feet in three days.

Rutland. R. J. McCadden; sec. 5: well, 32 feet; soil 2; sand and fine gravel, somewhat clayey, 6; yellow till, 5; blue till, about the same as the yellow till in respect to hardness, 16: sand and gravel, 2 feet; blue till, 1 foot and extending below; water rose ten feet in one day.

Fairmont (also see page 477). Occidental hotel: well, 85 feet; yellow till, 24; softer blue till, 60; water rose about forty feet from gravel and sand at the bottom.

R. M. Ward; Fairmont: well, 40; soil, 2; quite hard yellow till, 22; blue till, softer, but very tenaceous, 16 feet and lower; water seeps in a moderate supply from the lower part of the yellow till.

Silver Lake. A. W. Young; sec. 29: well, 30 feet; soil, 2; yellow till, picked, 8 feet; blue till, 20 feet, harder to excavate because more tenaceous, but not harder to drive a pick into; gravel, one inch; underlain by fetid clay, containing decaying vegetation; water rose six feet in a quarter of a day from the gravel. This blue till contained a few pieces of lignite, the largest being six inches in diameter. Pieces of wood are also found occasionally in the till by wells in this vicinity, and in one instance a log a foot in diameter was encountered thirty feet below the surface. In digging O. H. Roice's cellar on sec. 27 of this township, gasteropod shells were found at a depth of six feet below the surface, in a layer of sand and gravel two inches thick, overlain and underlain by yellow till. These organic remains, like the chains of lakes, are records of an interglacial epoch.

East Chain. W. H. Rich; at the village, sec. 7: well, 44; soil, 2; yellow till, 6; reddish gravel, 4 feet; light-colored till, 20 feet; dark, bluish "hardpan," six inches; gravel, 3 feet; blue till, 8 or 9 feet, and extending below; a running stream of water was found in the gravel at 32 to 35 feet, not rising; it was running toward springs that occur a little above the level of East Chain lake, which is a short distance west of the well.

Tenhassen. William Merry; sec. 29: well, 21 feet; soil, 2; yellow till, 19; water rises twelve feet from sand at the bottom. No wells in this region exceed 25 feet in depth, and the water is uniformly good.

Lake Belt. J. H. Headly; S. W. ¼ of sec. 18: well, 18 feet deep; soil, 2; light gray till, 16; water rose four feet from springs in the lower part of the till.

Manyaska. Henry Hulsemann; N. E. ¼, sec. 12: well, 26; soil, 2; yellow till, spaded, 24; water seeps; about a dozen small pieces of lignite were found.

Frederick Hulsemann; N. W. ¼ sec. 12: well dug 18 feet, and bored 25 feet; soil, 2; yellow till, spaded, 10; harder blue till, 31 feet; at 43 feet from the surface the auger suddenly fell six inches, and water rose to be eleven feet deep in the dug portion of the well in five minutes, and in two hours or less reached its permanent level, two feet below the top of the well. This water at first was dark, as if stained, and its taste and smell were offensive; but after a few months it became good water, and had continued so three years, being regarded at the time of this information, in 1880, as good as any in this region. Another well, fifteen rods northwest from the foregoing and on land ten feet higher, was yet only 18 feet deep, being soil, 2 feet; yellow till, 14 feet, with streaks of sand; and dark gray, very compact "hardpan," picked, and holding together in masses of a hundred pounds' weight, about 2 feet. During excavation the water broke through this hardpan, and rose to seven feet below the top very suddenly, bringing up large quantities of dark gray quicksand. This well caved in after two weeks. Numerous pieces of lignite were found in both these wells.

A large chalybeate spring, of reputed medicinal virtue, occurs in the N. E. ¼ of sec. 2, at the south side of Lily creek, which is the outlet of Fox lake at high water.

Railroad well at Sherburne, in the S. W. ¼ of sec. 7: 113 feet deep; dug seven feet square to a depth of 76 feet, and bored six inches in diameter below; soil, 3 feet; yellow till, 7 feet; from gravelly streaks in this till eight feet below the surface, water came in large amount, filling the well eight feet deep in twelve hours (probably at a wet season, not considered sufficient for the requirements of the railroad); blue till, much harder, 90 feet; gravel, 2 feet, with considerable water, which rose forty feet, or more, but was not supposed to be a large enough supply; blue till, still harder than before, 6 feet; gravel, also yielding water, 2 feet; dark bluish "hardpan," exceedingly hard, 2 feet; and gravel, 1 foot, reaching lower. The water that had come into the well from the gravel at 100 to 102 feet, was shut off by the tubing; and when the last stratum of gravel was struck, the water that came at the depth of eight feet from the yellow till was drained away into this lowest gravel, from which gas rose with a loud roaring and filled the well. This appears to have been choke-damp, or carbonic acid. At this juncture, some implement having been accidentally dropped into the well, the foreman of the work commanded one of his men to go down for it, and, being angry at his refusal, himself rashly descended and was immediately killed by this gas, after it had been ascertained that fire was extinguished by it. The water from the yellow till continued to sink into this gravel during several weeks, at the close of which the pipe became clogged and the well has since been full of water.

Jay. In the S. E. ¼ of sec. 12, a half mile west of Sherburne, a second railroad well, 90 feet deep, was soil and yellow till, 10 feet; and blue till, with occasional gravelly streaks, yielding some water but not enough, 80 feet, and extending below. The water-tank at this place draws from a lake.

Besides the well reported on page 477, another on Cargill, Van & Co.'s farm, in sec. 14, thirty rods south from that well, is till, to gravel and sand at 50 feet, from which water rose twenty-six feet in fifteen minutes. The water of this is a larger supply and better in quality than that of the deep well, which is much harder, having more of the carbonates of lime and magnesia in solution, and consequently objectionable for use in steam-boilers, because of its greater amount of mineral residue, forming scale.

Fox Lake. Henry Miller; S. E. ¼ of sec. 26: well, dug 24 feet and bored 15 feet; soil, 2 feet; yellow till, spaded, 12; sand, 3 feet; yellow sand and clay, with gravelly streaks, mainly very fine and dry, very hard, 3 feet; iron-rusted gravel, interbedded with white gravel, 4 feet, containing many fragments of lignite up to six or eight inches in length, mostly in the white layers; gravel, sand, and clay, interstratified, mostly gray or yellowish, mainly hard, but with some very soft layers, 15 feet, to the bottom of the boring, where the auger became immoveable, and was left, in either a log of wood or a mass or bed of lignite. This well is used, being supplied by seeping water, which, like nearly all the wells of this region, is of excellent quality.

MATERIAL RESOURCES.

The fitness of Watonwan and Martin counties for farming and herding is their chief source of wealth; and by this they are capable of supporting

a large and prosperous population, mainly agricultural, with towns and villages as required for manufacturing and centers of trade.

Water-powers. The only water-power used in Watonwan county is that of the Madelia mills, owned by J. T. Fisher, on the Watonwan river about a mile west of the town; head, eleven feet; a flouring mill, doing custom grinding; three run of stone. Other water-powers may be utilized on the main stream and on both its north and south branches.

In Martin county, also, only one water-power is now employed, this being at the flour mill of East Chain, owned by Ruble & Murphy, of Albert Lea, but leased to S. Vermilya; the fall or head is eight feet.

A dam was once built at or near the outlet of lake George in the Central chain of lakes, raising lake George six feet, and flowing back to Hall's lake, in sections 19 and 20, Fairmont, this being raised about one foot. A grist-mill, said to have a head of six or eight feet, several years ago stood a little below the foot of Wilmont lake, one of the same chain of lakes, in the northwest part of Silver Lake township. Good water-powers are also available on Elm, Center, and South creeks.

Building stone. No stone-working has been done in these counties, except the use of boulders, chiefly granite, syenite, and gneiss, with occasional slabs of limestone, and in one instance a large mass of probably Cretaceous sandstone, found, as already stated, in section 6, Rutland. These erratics of the drift, though dissimilar, make substantial, rough foundations, cellar walls, and curbing in wells.

Brick-making is not carried on in either of these counties; but about ten years ago red bricks of good quality were made on the north side of Watonwan river, a little east of the bridge close southwest of Madelia; and again a year or two after this, light-reddish bricks were made at Saint James.

No lime-burning was learned of in these counties.

Peat occurs in numerous places, and near Fairmont has been prepared for use as fuel by Mr. A. L. Ward.

ABORIGINAL EARTHWORKS.

Two interesting artificial mounds, of the usual form like a low, round dome, are situated about forty rods east and southeast of the mill at the north end of East Chain lake, and about forty feet above the lake. These have been opened by Mr. S. Vermilya, who reports that the northern mound here, about sixteen feet across and two feet high, was found to contain much wood in poles four to six inches in diameter, suggesting that they might originally have served as a roof, covered by earth. Two skeletons, thought to have been male and female, were here entombed in a sitting posture, about three feet below the natural surface or five feet below the top of the mound. With these were found an iron spoon, wasted by rust; iron handles and fragments of leather, as of a valise; two pairs of scissors, and a thimble, made of a brass-like alloy; bracelets of similar metal, less corroded; and many beads of glass and other material, mostly, like the metallic articles, not of Indian manufacture, but made by white men.

About twenty rods south of this mound, a second, only elevated one foot above the ordinary surface, with its top apparently sunken in, also contained poles of wood. The only skeleton found here was apparently that of a woman, buried, unlike those of the first mound, in a reclining posi-

tion, and enclosed in a rude coffin, which was a dug-out canoe, cut in two at the middle, one part being placed above and the other beneath the body. Among the articles found here were beads; one pair of scissors; two thimbles, in a wooden tray; and a kettle of sheet-iron. Mr. Vermilya reports, within a distance of a half mile from these, several other artificial mounds, one to three feet high.

In the northeast corner of section 6, Rutland, a group of eight mounds (Fig. 31), of the common round form and varying from one and a half to three feet in hight, lies between Elm creek and Martin lake, on land about thirty feet above them. Six of these are in a straight line, which bears S. 60° E., and reaches about thirty rods, or some three-quarters of the distance from the creek to the lake. Mr. R. J. McCadden and others opened four of these mounds in 1879, finding several skeletons in each, buried about one foot below the natural surface, in a sitting position, facing the east, of stature five and a half to six feet high. Implements and utensils found were twenty or thirty unfinished flint arrow-heads in one place, and with them a wedge-shaped stone, supposed to be for skinning, and a pipe, about five inches long, of the form and proportions shown by figures 32 and 33, cut out of some dark gray stone; a few flint arrow-heads here and there in the other mounds; and in the largest mound of the group (not that which contained the many arrow-heads and the pipe), a small, unbroken cup (fig. 34), three inches in diameter and two and one-third inches high, with an aperture of one and a half inches, having a nearly uniform thickness of an eighth of an inch, made of baked clay, gray in color, slightly mixed with gravel on the inner side. This cup is perforated just below its rim by four holes, in pairs close together on its opposite sides. No articles of metal were found.

These two localities are in Martin county; no mounds were observed, nor heard of by inquiry, in Watonwan county.

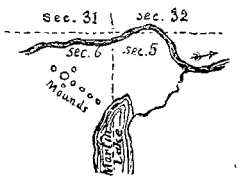


FIG. 31.
ABORIGINAL MOUNDS, SEC. 6, RUTLAND.

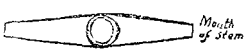


FIG. 32.
PIPE, VIEW FROM ABOVE.

FIG. 33.
PIPE, SIDE VIEW.

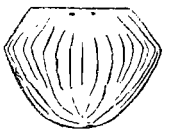


FIG. 34.
CUP.

ARTICLES FOUND IN MOUNDS, SEC. 6, RUTLAND.

PLATE 18

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

COTTONWOOD AND JACKSON COUNTIES

BY WARREN UPHAM

Explanation

- Till, flat or undulating
- Moraine Till, rolling
- Moraine Till, roughly hilly
- Potsdam Quartzyte

Glacial Drift

Contour Lines are drawn approximately for each 50 feet above the sea.

REDWOOD COUNTY

BROWN COUNTY

MURRAY COUNTY

NOBLES COUNTY

WATONWAN COUNTY

MARTIN COUNTY

ANN HIGHWATER GERMANTOWN

WESTBROOK STORDER AMBOY COTTON PORTLAND

COTTONWOOD

ROSE HILL AMO DALE CARSON MOUNTAIN LAKE

SOUTH BROOK SPRINGFIELD GREAT BEND LAKESIDE

WELMER

LA CROSSE DELAFIELD CHRISTIANA KIMBALL

OKABENA WEST ALBA HERON LAKE HERON LAKE BELMONT ENTERPRISE

JACKSON

EWINGTON RUSH HUNTER DES MOINES WISCONSIN

ROUND LAKE SIOUX VALLEY MINNEOTA MIDDLETOWN PETERSBURG

T. 108 N.
T. 107 N.
T. 106 N.
T. 105 N.
T. 104 N.
T. 103 N.
T. 102 N.
T. 101 N.

R. XXXVIII W. R. XXXVII W. R. XXXVI W. R. XXXV W. R. XXXIV W.

STATE OF IOWA

PLATE 20.

CHAPTER XVI.

THE GEOLOGY OF COTTONWOOD AND JACKSON COUNTIES.

BY WARREN UPHAM.

Situation and area. The map of these counties forms plate-pages 19 and 20. Cottonwood is one of the second tier of counties north of the Iowa line, from which it is separated by Jackson county. From Saint Paul and Minneapolis southwest to Windom and Jackson is about 130 miles. From La Crosse and the Mississippi river west to the eastern boundary of these counties is 180 miles; they are 30 miles long from east to west; and from their west line onward to the east line of Dakota is 50 miles.

Cottonwood county has a length of five townships, and a width from north to south of four; except that on the northeast two of the townships that would be included in this county if it were a complete rectangle, belong to Brown county. With this reduction, Cottonwood county has eighteen townships, each six miles square. The only towns and villages of this county are in the southeast part, on the line of the Saint Paul & Sioux City railroad. These are Windom, the county seat, situated in Great Bend township, Bingham Lake, in Lakeside, and Mountain Lake. Cottonwood county has an area of 650.39 square miles, or 416,250 acres, of which 8,655.65 acres are covered by water.

Jackson county is a rectangle, five townships in length from east to west and four in width from north to south. The important towns are Jackson, the county seat, in Des Moines township, and Heron Lake, in Weimer township. This county has an area of 722.66 square miles, or 462,501.20 acres, of which 16,434.75 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The northwest part of Cottonwood county, including Germantown, Highwater, Ann, Westbrook, Storden, northwestern Amboy, and most of Rose Hill, is drained to the Cottonwood river, which flows through southern Redwood county, only a few miles farther north, and enters this county for a short distance in the northeast corner of Germantown. Its tributaries from Cottonwood county, in their order from west to east, are Dutch Charley's, Highwater, Dry and Mound creeks. The largest of these is Highwater creek, whose sources are several lakes in Rose Hill township, only three to seven miles from the Des Moines river. Its course in this county is east-northeast, about eighteen miles.

The Little Cottonwood river, tributary to the Minnesota a few miles below the Cottonwood river, rises nearly at the center of Cottonwood county, and its first ten miles, flowing northeast, are in Amboy and Delton townships. Its farther extent of about thirty miles eastward through Brown county, is approximately parallel with the Big Cottonwood, and mainly three to six miles distant to the south from that river.

A tract in the east part of Cottonwood county, reaching west to its center, including Selma, Mountain Lake, Carson, the south half of Delton, and the northeast part of Dale, is drained by the head-streams of the Watonwan river, tributary to the Blue Earth and, by that, to the Minnesota. The area in Cottonwood county included within the basin of the Minnesota river is approximately 450 square miles.

The remainder of this county, including its southwestern townships, an area of about 200 square miles, is drained by the Des Moines river, which flows in a zigzag course, crossing South Brook, Springfield and Great Bend diagonally, having a general southeast direction in South Brook and Great Bend, but making an offset in Springfield by running eight miles northeasterly. Harvey creek, the outlet of lake Augusta in northeastern Amo, entering the Des Moines at its big bend in the southwest corner of Dale, is its largest tributary from the north in this county; from the south it receives the outlet of Spring lakes, which lie in the southwest part of Great Bend, and the outlet of Heron lake.

Among the *lakes of Cottonwood county* the following merit enumeration: Mountain lake, two miles long and from a half mile to one mile wide, two miles southeast from the depot and town of

Natural drainage.]

this name; Bingham lake, one mile long from northeast to southwest, close north of the town to which its name is given; Clear, Cottonwood, Wolf, Summit and Glen lakes, one-third to two-thirds of a mile long, in the west and southwest portions of Lakeside, one to three miles eastward from Windom, beautiful lakes of clear water, divided by irregular hilly or rolling areas of prairie, and skirted by narrow woods; Fish lake, nearly two miles long from northeast to southwest, and one-fourth to two-thirds of a mile wide, crossed by the south line of Lakeside and having about half its area in Jackson county; the Spring lakes, reaching two and a half miles from north to south, four miles west of Windom; the Three lakes, and Swan lake, each about one mile long, in Dale; Rat, Long, Eagle and Maiden lakes, from one-third to one mile long, in the south half of Carson; lake Augusta, about one and a half miles long and a half mile wide, in Amo; Hurricane lake, more than a mile long from north to south, lying in section 31, Highwater, and section 6, Storden; Double lake, of similar extent and trend, in sections 23 and 26, Westbrook; Berry and Twin lakes, with others, varying from a quarter of a mile to about one and a half miles in length, trending to the south or southeast, in Rose Hill; Oaks lake, one and a half miles long from north to south, but narrow, lying in section 32, Rose Hill, and sections 5 and 8, South Brook; and Talcott lake, in sections 19 and 30, South Brook, a mile long from north to south, with the Des Moines river flowing through its northern end.

Jackson county is partly drained by Elm creek to the Blue Earth and Minnesota rivers; partly by the Des Moines river, which crosses Iowa and enters the Mississippi at the southeast corner of that state; and partly by the Little Sioux river, which joins the Missouri thirty-eight miles north of Omaha.

About 90 square miles of northeastern Jackson county are tributary to the Minnesota river by Elm creek, which flows east through Martin county and enters the Blue Earth river after a course of forty miles. Its sources, in Belmont and Christiana, are only two to four miles east of the Des Moines river.

About 420 square miles of this county lie within the basin of the Des Moines, which flows, after leaving Cottonwood county, in a south-southeast course. Its only important affluent in these counties is the outlet of Heron lake, which comes into it nine miles west of Windom.

Some 210 square miles on the southwest are in the basin of the Missouri, being drained by the head-streams of the Little Sioux river.

Lakes in Jackson county. East of the Des Moines river the only notable lakes in Jackson county are Fish lake, about two miles in length, on the north line of Christiana, half of it being in Cottonwood county; lake Otto and Independence lake, each about a half mile long, respectively on the east and south boundaries of Christiana; and Lower's lake, of similar size, near the center of the township.

West of the Des Moines, the largest body of water in this county and in all southern Minnesota is Heron lake, eleven miles long, with a width of two and a half miles in its central part, diminished to a half or a fourth of a mile at each end, giving it an area of about fourteen square miles. This lake, reported to be only from five to fifteen feet deep, is mainly clear, but has some portions that are reedy, with marshy shores, affording a paradise to ducks, herons and blackbirds. Other noteworthy lakes in this part of Jackson county are lake Carroll, a half mile long from northeast to southwest, in northern Delafield; Minneseka lake, a mile long from east to west,

crossed by the west line of this township; Flaherty's lake, a mile or more in length from north to south, and a half mile wide, in sections 6 and 7, Heron Lake; Boot lake, a mile long from north to south in sections 30 and 31, Belmont; Clear lake, exceeding a mile in length from east to west and about three-fourths of a mile wide, at the west side of Des Moines; Loon lake, nearly two miles long from north to south, crossed by the east line of Minneota; the Little Clear lakes, in sections 22 and 23 of this township; Little Spirit lake, about a mile in diameter, lying mainly in section 35, Minneota, divided from Spirit lake in Iowa by only a narrow low ridge of gravel and sand, pushed up by ice during the recent period; Skunk lake, a mile long from east to west, lying mostly in the south half of section 22, Sioux Valley; Rush lake, also a mile long, but trending from north to south, in the southwest part of the same township; Plum Island lakes, a half mile and one mile long, near the middle of Round Lake township; Round lake, a little more than a mile n diameter, in the northwest part of this township; and State Line lake, a mile long from north to south, situated at the southwest corner of the county.

Topography. In northern Cottonwood county a massive ridge of the red Potsdam quartzyte extends twenty-five miles from west to east through Storden, Amboy, Delton and Selma, terminating in the west edge of Adrian, the northwest township of Watonwan county. This highland is mostly covered by a smooth surface of till, but has frequent exposures of the rock. Its altitude increases from 100 feet at its east end to 300 feet westward, above the broad, slightly undulating sheet of till, which, excepting a morainic tract in Stately, covers the region toward the north. The hight reached at the top of this quartzyte ridge, 1300 to 1500 feet above the sea, is a permanent rise of the land, which to the south and southwest holds nearly this average elevation, with a general ascent westward.

This ridge was probably considered by the early French explorers as the northeast border of the *Coteau des Prairies*, which name, meaning the Highland of the Prairies, they gave to an elevated tract, extending about two hundred miles from north-northwest to south-southeast in eastern Dakota and southwestern Minnesota. Of this highland in Cottonwood and Murray counties, Nicollet says:* "Under the forty-fourth degree of latitude, the breadth of the Coteau is about forty miles, and its mean elevation is here reduced to 1,450 feet above the sea. Within this space its two slopes are rather abrupt, crowned with verdure and scolloped by deep ravines thickly shaded with bushes, forming the beds of rivulets that water the subjacent plains." It is not continuously recognizable as a great topographic feature south of this quartzyte ridge.

The Little Cottonwood river and the north branch of the North fork of Watonwan river flow northeasterly through gaps in the range of quartzyte, a hundred feet or more below its crest, the former finding its passage at the middle of the north half of Delton, and the latter about a mile west from the center of Selma. Excepting at these points, the ridge is unbroken and uplifts a broad, smoothly rounded top, covered with till through which the quartzyte has occasional outcrops. It extends in a course a little to the north of west twelve miles from the north part of section 25, Selma, to the north part of sections 9, 8 and 7, Delton; and thence a little to the south of west ten miles to Highwater creek at the middle of Storden township. In its east half, through Selma and Delton, this ridge has a width that increases toward the west from a half mile to one or two miles, elevated 50 to 100 feet above the average of the land for the next five or six miles to the south, and twice this hight above the country which it overlooks northward to the horizon. Both slopes of the range have a gentle descent, that to the north occupying a width of one to two miles, and reaching from section 7, Delton, to the falls formed by this quartzyte on the headstreams of Mound creek, in the southwest corner of Brown county, and in the N. E. ¼ of section

Report on the upper Mississippi river, 1843, p. 10; consult also plate 7 and page 68 of the present volume.

Topography.

36, Germantown. In the central and southwest part of Amboy and the east half of Storden, this highland, besides slowly increasing in elevation westward, expands to a greater width, and forms an approximately level plateau of till, one to three miles wide, with outcrops of the quartzyte only upon the slopes which descend from it. The most southern exposures of this rock in Cottonwood county are in the west part of sections 6 and 7, Dale, and in section 12, Amo, on the western descent from the most southern part of this plateau, which here in northwestern Dale is 75 or 100 feet above the remainder of this township and its Three lakes, and about 150 feet above lake Augusta on the west.

This area of Potsdam quartzyte is the only part of Cottonwood county which has exposures of the bed-rocks, the remainder being moderately undulating or rolling and sometimes hilly glacial drift. The general slope, as already stated, rises from east to west, and at the west side of Amo and in Rose Hill this drift attains as great an altitude as the quartzyte range eight miles northeast in Amboy and Stordon.

The townships of Westbrook, Ann, Highwater and Germantown, lying north of this hight of land in Rose Hill, Amo and the ridge of quartzyte, have mostly a smoothly rolling contour, with the crests of swells fifteen to thirty feet above the depressions. The creeks which drain this district northward to the Cottonwood river flow in valleys that they have eroded 20 to 40 feet below the average surface.

The whole of Jackson county, like the northwest and south parts of Cottonwood county, is so deeply covered by the glacial drift that it has no outcrop of the underlying rocks. Southwest and south of the quartzyte ridge, these counties are crossed by a belt of knolly and hilly or prominently rolling moraınic drift, two to seven miles wide, which reaches from Rose Hill southeast to the Blue mounds west of Windom, and thence south through the center of Jackson county to the west side of Spirit lake. From the vicinity of Windom a branch of this moraine extends ten miles north through the west part of Lakeside and Carson. The same knolly and broken contour of the drift is found also in the south part of Sioux Valley and in Round Lake township, on the southwest border of Jackson county. Excepting these morainic tracts and the ridge of quartzyte, these counties are a smoothly undulating, and in part almost flat, sheet of till, ascending with a very gentle slope from east to west, enclosing lakes here and there in its depressions, slightly channeled by creeks and deeply cut by the Des Moines river. Many further details respecting the contour of the drift are presented in a later part of this chapter.

The valley of the Des Moines river in South Brook, the most southwest township of Cottonwood county, is less distinct in its outlines, and its depth is less, than in any other part of its extent below lake Shetek. South Brook has mostly a rolling contour of massive swells, variable in their forms, trends, and extent, rising 20 to 50 feet above the Des Moines river, which flows among them in an irregular course, generally without any well-defined valley of bottomland and bluffs, but turned here and there by small undulations. In section 19 it passes through the north end of Talcott lake, which lies in a shallow basin of the drift-sheet, covering nearly a square mile, but only from five to eight feet deep.

In Springfield where the Des Moines flows northeast, at right angles to its course both above and below, it again occupies a definite valley, channeled 50 to 75 feet below the average hight of

the rolling surface on either side. At the northeast corner of this township is the great bend of the Des Moines. Here it enters a valley transverse to its course through the last eight miles, and is carried in it thence to the southeast. This valley has a nearly flat alluvial bottomland, a third to a half of a mile wide, enclosed by bluffs 50 to 60 feet high. It continues two or three miles northerly from the great bend, with the same width and depth; and is less distinctly marked three or four miles farther, along the upper part of Harvey creek to lake Augusta. The excavation of this channel was probably effected by floods discharged from glacial melting, while the receding ice-sheet still covered these counties farther east. In the central part of Great Bend township the river is bordered on the west by morainic knolls and small ridges of rocky till, which rise successively one above another to the top of the Blue mounds, one to one and a half miles distant; and in the vicinity of Windom the ascent from the river eastward has a similar contour.

Through Jackson county the valley of the Des Moines is 100 to 150 feet below the average hight on each side, and is from one-third to two-thirds of a mile wide between the tops of its bluffs, which in the north part of the county rise in knolly and irregular slopes of morainic drift, but at Jackson and southward have generally the nearly straight course and steep ascent characteristic of ordinary fluvial erosion. At Jackson the immediate river-bluffs are about 100 feet high, but there is a further rise of the moderately undulating expanse of till on each side, amounting to 50 or 75 feet within a mile or less from the top of the bluffs. This town is built on four terraces of modified drift, successively about 20, 30, 40 and 50 feet above the river, together occupying a width of one-fourth to one-third of a mile. They are mostly composed of sand and gravel for several feet next below the soil; but in some places the underlying till reaches quite to the surface.

Distances along the Des Moines river, measured in direct lines between its principal bends, are as follows: from its source to the foot of lake Shetek (this portion being commonly called Beaver creek), 24 miles; to a point on the south line of Cottonwood county, two miles north of the north end of Heron lake, 48 miles; to its great bend, 56 miles; to Windom, 63 miles; to Jackson, 81 miles; to the state line, 91 miles; and to its mouth at Keokuk, about 385 miles. Thus a little less than one-fourth of its entire length lies in Minnesota.

Elevations, Saint Paul & Sioux City division, Chicago, Saint Paul, Minneapolis & Omaha railway.

From profiles in the office of T. P. Gere, superintendent, Saint Paul.

	Miles from St. Paul.	Feet above the sea.
Mountain Lake, depot	137.0	1300
Bingham Lake, depot	143.2	1420
Summit, grade	144.1	1437
Windom	147.8	1353
Des Moines river, water	148.1	1331
Bluff siding	149.7	1425
Wilder	154.0	1448
Heron lake, water	159.0–159.5	1403
Heron Lake, depot	160.3	1417

Elevations, Southern Minnesota division, Chicago, Milwaukee & Saint Paul railway.

From George B. Woodworth, assistant engineer, La Crosse.

	Miles from La Crosse.	Feet above the sea.
Top of bluff at junction of branch to Jackson depot	209.1	1446
Des Moines river, water	211.8	1288
Des Moines river, bridge	211.8	1353
Summit, grade	216.6	1517
Lakefield	220.6	1463
Okabena	229.1	1410
Crossing Saint Paul & Sioux City railroad	232.2	1414

The highest portions of Cottonwood county, about 1500 feet above the sea, are in Rose Hill township, in western Amo, and the plateau upon the

west part of the quartzyte ridge in southeastern Storden and southwestern Amboy, and the tops of the Blue mounds, which are 1450 to 1525 feet above the sea. The lowest land of this county, nearly five hundred feet below these tracts, is where the Cottonwood river enters the northeast corner of Germantown, at a hight of about 1030 feet above the sea. The elevation of the Little Cottonwood river where it leaves the county is estimated to be 1150 feet; and of the most northern tributary to the Watonwan river, at the east line of Selma, 1100. The Des Moines river descends in this county approximately from 1400 to 1330 feet above the sea.

Estimates of the average hight of the townships of Cottonwood county are as follows: Selma, 1225 feet above the sea; Mountain Lake, including two governmental townships, 1300; Delton, 1325; Carson, 1375; Lakeside, 1410; Germantown, 1200; Amboy, 1400; Dale, 1450; Great Bend, 1410; Highwater, 1225; Storden, 1400; Amo, 1450; Springfield, 1430; Ann, 1300; Westbrook, 1420; Rose Hill, 1450; and South Brook, 1425. The mean elevation of Cottonwood county, derived from these figures, is 1360 feet.

In Jackson county the greatest altitudes are attained by the inner terminal moraine which extends from north to south through the center of the county, its crests being 1475 to 1550 feet above the sea; and by the outer terminal moraine, which has about the same elevation from Skunk and Rush lakes to Round and State Line lakes in the southwest corner of the county. The descent of the Des Moines river is estimated to be eighty feet, from 1330 at the north to 1250 feet, approximately, where it crosses the state line, at the lowest point in this county. Mean hights of the townships of Jackson county are estimated as follows: Kimball, 1350; Enterprise, 1375; Wisconsin, 1400; Petersburg, 1375; Christiana, 1400; Belmont, 1410; Des Moines, 1420; Middletown, 1425; Delafield, 1440; Heron Lake, 1460; Hunter, 1475; Minneota, 1460; Weimer, 1415; West Heron Lake, 1420; Rust, 1440; Sioux Valley, 1460; La Crosse, 1425; Alba, 1450; Ewington, 1500; and Round Lake, 1520. The mean elevation thus obtained for the whole county is 1430 feet.

Soil and timber. The soil of Cottonwood and Jackson counties has the same nearly uniform fertility that characterizes all southern and western Minnesota. A black, sandy clay, with some intermixture of gravel, and containing occasional boulders, forms the soil, which has been colored to a

depth of about two feet below the surface by decaying vegetation. Unmodified glacial drift or till, the same as the soil, excepting that it is not enriched and blackened by organic decay, continues below, being yellowish gray to a depth of 10 or 20 feet, but darker and bluish beyond, as seen in wells. This deposit contains many fragments of magnesian limestone, red quartzyte, granites and crystalline schists; and its fine detritus is a mixture of these rocks pulverized, presenting in the most advantageous proportions the mineral elements needed by growing plants. Wheat has been the principal crop, but stock-raising has also received much attention in Jackson county during several years past. A large variety of crops is profitably cultivated throughout this region, including wheat, oats, corn, garden fruits and vegetables, potatoes, and hay. In general, Jackson and Martin counties have a somewhat more sandy soil than the districts adjoining them on the east, north and west, and appear to be therefore slightly less adapted for wheat-raising. Besides this staple product, horses and cattle, pork and beef, butter and cheese, have become considerable exports.

From 1873 to 1876 Cottonwood and Jackson counties, in company with all southwestern Minnesota, were distressed by the ravages of the Rocky Mountain locust. To many the work of plowing and sowing, and the wheat sown, were total losses during these years. In 1880 frequent groves were noticeable between Fairmont and Worthington, which had been set out to shield farm-houses from the wind, and still remained, though the buildings were gone and the farms deserted, telling where in this struggle the grasshoppers had conquered. Though the wheat was nearly everywhere eaten by them so that no harvest could be saved, the prairie grass suffered only slightly, and from this epoch herding has taken an important place in the agriculture of Jackson and Martin counties.

The opinion prevails, and seems to rest upon a correct knowledge of facts, that the yield of wheat generally in the southern tier of counties of Minnesota during the past fifteen years or so, averaging ten to fifteen bushels per acre, has been only half or two-thirds as great as during the preceding ten or fifteen years. Much land remains that was never broken with the plow, and this contrast in productiveness is exhibited by newly broken ground in all respects similar to adjacent tracts that were first cultivated twenty or thirty years ago. It appears also that the early immigrants found wetter seasons, the sloughs more frequently impassable, and the lakes mostly standing at somewhat higher levels, than during the fifteen years next before 1880. To differences in rain-fall thus indicated, and differences in temperature and winds, and in their distribution through the year, making up the climate as a whole, we must attribute the diminution in the wheat crop. Probably these general climatic changes will be found to be periodic; lessened precipitation of rain and snow, and reduced yields of wheat through several years, being succeeded by a term, perhaps of equal duration, bringing as great rainfall, and as plentiful harvests, as have ever been recorded. The more wet years from 1880 to 1882 may mark the beginning of a period especially favorable for wheat-raising in southern Minnesota.

These counties are natural prairie, affording rich pasturage, and ready for the plow. Less than a hundredth part of their area is wooded. This includes small groves and narrow skirts of timber and brushwood about

the shores of lakes, along the large creeks, and especially along the whole extent of the Des Moines river. The following species of trees and shrubs are found at Talcott lake: American or white elm, bur oak, white ash, box-elder, black walnut, willows, prickly ash, smooth sumach, frost grape, Virginia creeper, climbing bitter-sweet, wild plum, choke-cherry, black raspberry, rose, thorn, smooth wild gooseberry, and wolfberry, common; red or slippery elm, cottonwood, hackberry, waahoo, and black currant, less frequent. Basswood grows at Oaks lake, a few miles farther north. About Spirit lake, which lies in the north edge of Iowa and extends into the south part of section 36, Minneota, the timber consists principally of bur oak, white and red elm, white ash, basswood, sugar maple, box-elder, black walnut and cottonwood.

GEOLOGICAL STRUCTURE.

Potsdam quartzyte. The only exposures of bed-rock in this district are the red quartzyte which forms a prominent ridge in the north part of Cottonwood county, reaching into the edge of Watonwan and Brown counties. From the most eastern to the most western outcrop of this rock is a length of twenty-three miles; and the width upon which it is occasionally exposed increases from a half mile or less at the east to six miles at the west. The contour of this area has already been described as rising in a massive highland of rock, mostly covered by a smooth sheet of till, with gracefully rounded top and moderate slopes. The general character of this formation, and the location, extent, and special features of its outcropping ledges are to be noted here.

In Courtland, two miles east of New Ulm and about thirty miles east-northeast from this ridge in northern Cottonwood county, and again in Pipestone and Rock counties, fifty miles west-southwest from this ridge, the same rock-formation has extensive exposures, and it continues westward in Dakota to Dell Rapids and Sioux Falls on the Big Sioux river, and to Rockport on the James river, seventy miles west of Minnesota, and about a hundred and eighty miles west-southwest from New Ulm. All these outcrops are mainly very hard, fine-grained quartzyte, differing in color from pinkish gray to dark dull red, always having some red tint; and varying in the thickness of its beds from a few inches, or sometimes only a half inch or less, to one or two feet. It is usually perceptibly tilted, with considerable variability in the direction of its dips, which vary in amount from one or two to fifteen or twenty degrees, and rarely attain an inclination of forty-five degrees. This quartzyte is a metamorphosed sandstone. At a few places it occurs in an imperfectly indurated condition, being a more or less crumbling sandrock, composed of water-rounded grains. Sometimes, too, it is a conglomerate, enclosing abundant water-worn pebbles up to an inch in diameter, what was originally an ordinary fine gravel having become so cemented as to form a very compact and hard, tough rock; and by diminution in the number of pebbles scattered through it, the formation exhibits all grades between this pudding-stone and its

typical condition as a quartzyte. Again, it occasionally contains layers, from less than an inch to several feet thick, of argillaceous rock, so fine-grained and even in its texture as to appear macroscopically homogeneous, doubtless metamorphosed from deposits of fine silt or clay in the midst of beds of sand; commonly dull red, but often mottled with pale spots or striped by the same lighter tints in parallelism with its stratification; soft enough to be easily carved and polished, and in its best varieties entirely free from grit. This has been named *catlinite*, and its finest layer is that which has been worked by the Indians, to whom it is still reserved, at the celebrated Red Pipestone quarry.

The planes of bedding of this quartzyte frequently show very distinct and beautiful ripple marks, such as are made by waves upon the sandy shore and bottom of lakes or of the sea. No fossils have been detected in this formation, as here described in southwestern Minnesota and southeastern Dakota; and fucoid impressions, rarely observed, are the only remains of life yet found in the probably equivalent Cupriferous series of red quartzytes and sandstones interstratified with thick basaltic overflows and beds of tuff and tufaceous conglomerate, which is very extensively developed about lake Superior. The quartzyte from New Ulm to the James river is closely like the sandstone and quartzyte associated with trap rocks in northeastern Minnesota, in northern Wisconsin and northern Michigan; but its deposition was not similarly accompanied by outflows of igneous rock, nor has this formation in southern Minnesota been intersected by trap dikes. Foster and Whitney referred these rocks in the region of lake Superior to the Potsdam age, considering them the western equivalent and representative of the Potsdam sandstone in New York; and the explorations by this survey of their continuation into northeastern Minnesota sustain this conclusion,* while the observations of this quartzyte outcropping in the southwest part of the state and farther west indicate that it belongs to the same epoch. This formation underlies the Calciferous or Lower Magnesian series, which outcrops along the lower part of the Minnesota river from a point fourteen miles east-southeast of New Ulm, and along the Saint Croix and Mississippi rivers.

In the N. E. ¼ of section 25, Selma, this red quartzyte is exposed upon an eastward slope of till, with an area three rods long from northwest to southeast, and about a rod wide, rising some two feet above the general surface.

In the S. E. ¼ of section 23, Selma, this rock outcrops on a southward slope along a distance of about twenty-five rods from east to west, with a width of two or three rods and a hight of only one to two feet. It dips about ten degrees southward. Both these ledges have been slightly quarried. They are the ordinary, very hard quartzyte, intersected by systems of joints which give it a rhomboidal fracture. Other outcrops of the same stone, which have not been visited in this survey, occur northwestward at numerous places in this township and in the northeast part of Delton, upon the high ridge and in the hollow where the north branch of the North fork of Watonwan river crosses it.

The quartzyte also has frequent exposures in Delton along nearly the whole extent of the Little Cottonwood river through this township, and in its tributary ravines. In the east part of the S. E. ¼ of section 8, it has been much quarried in the banks and channel of this stream, supplying rough stone used for foundations, cellar walls, well curbing and culverts, or, by Russian immigrants, for chimneys, being sometimes teamed fifteen miles. It occurs in layers of all thicknesses up to two and a half feet, the thinly bedded portions, as usually, being much divided by joints into rhomboidal fragments a foot or less in length. The bedding planes are often ripple-marked over several square rods together, in parallel undulations about a quarter of an inch high and two to four inches apart from crest to crest. The dip is about 5° S. 20° W. This is some twenty rods east of the Little Cottonwood falls, where the same rock in its upper portion forms layers three to six feet thick, dipping about six degrees to the south, but only a few feet lower, near the level of the stream, is thin-bedded and somewhat contorted and irregular in stratification.

Quartzyte outcropping in the north part of the S. W. ¼ of section 18, Delton occurs in layers up to six inches thick, dipping about 3° S. 70° E. Twenty rods farther south it has a dip of the same amount but changed in direction to S. 40° E., all these bearings being referred to the true meridian. Its only exposures observed in the south half of this township are in the S. E. ¼ of section 30, where it is visible at numerous places along an extent of about an eighth of a mile in

*Consult Prof. Winchell's article on "The Potsdam sandstone," in the tenth annual report, pp. 123—136.

Potsdam quartzyte.]

a ravine tributary to the Watonwan river. No other outcrops were learned of upon the headstreams of this river farther eastward in Delton.

A ledge of this rock, very remarkably striated, as described on a following page, and bearing rude Indian inscriptions, is found on the ridge about a mile north-northeast from the Little Cottonwood falls and quarry, being in the north part of the N. W. ¼ of section 9, Delton. It has an area about twenty rods long from east to west, and four to eight rods wide. The dip of its stratification was not distinctly seen, but is believed to be about five degrees southward, which is the slope of the surface. Numerous figures are pecked on this rock, representing animals, arrows, etc., similar to those inscribed by the Indians on the quartzyte beside the boulders called the Three Maidens, near the Pipestone quarry. From this ledge westward the same typical quartzyte frequently outcrops upon the higher part of this ridge and on its northern slope through the northwest part of Delton, northern Amboy and northeastern Storden.

In the S. W. ¼ of section 2, Amboy, a ravine ten to fifteen feet deep extends east-northeast in a straight course about forty rods, varying from two to three rods in width, bordered by vertical walls, ten to fifteen feet high, of rough, thick-bedded quartzyte, of red or reddish gray color, nearly level in stratification, mostly much divided by joints. The eastern half of this ravine holds a long pool, ten to twenty feet wide, and five to eight feet deep. At the top of the wall of rock south of the west part of this pool, the much jointed, deep red, striated surface is in many places soft and like pipestone to the depth of an eighth of an inch; but within, these small jointed masses are gritty and hard, the pipestone being only a thin coating at the bedding-planes. At the western end of this ravine, on its north side, eight feet above the rivulet that flows east into the pool, this rock encloses a layer, nearly level, varying from four inches to a foot in thickness, somewhat like the pipestone of the famous quarry in Pipestone county, having nearly the same very fine texture and dark red color, but not so hard, and at this place, through its extent of twenty feet exposed to view, easily divisible into small flakes and fragments because of joints, and therefore not seen in any solid mass. The edge of this layer has been mostly removed by weathering to a depth of two to six feet into the wall of tough, reddish gray quartzyte, which overhangs and underlies it. The divisions of this very fine-grained bed from the coarse quartzyte are not definite lines, but these unlike sediments are more or less blended and interstratified through one to six inches. Both above and below, the quartzyte in some portions contains pebbles up to a third or half of an inch in diameter, and is quite variable in texture, but is nowhere finely laminated. At a few places the pipestone also is found to contain these small gravel stones; and a few fragments of pipestone up to three inches in diameter are seen enclosed in the quartzyte within one to two feet above the pipestone layer.

Picturesque falls are produced by this formation in the N. E. ¼ of section 36, Germantown. The rock here is mostly a very coarse-grained, thick-bedded sandstone, slightly iron rusty or reddish in color. Nearly all of it is somewhat friable, being thus unlike the other exposures of this formation in this county. In some portions, however, it is here very hard and compact, and then usually has a deeper red hue. Its dip is about 5° S. 10° E. Besides this general dip, the beds often show oblique lamination. This rock is in some places slightly conglomerate, holding pebbles of white quartz, and less frequently of red felsyte, or possibly jasper, the largest seen being an inch long. These falls are about two miles northeast from the gorge last described, being on a lower part of the same stream, which is one of the sources of Mound creek. Along its intervening course and within short distances from it on each side this formation has frequent outcrops, notably for a quarter of a mile south and southwest from the falls. The stream descends thirty feet in a succession of little cascades, within a distance of twenty rods; next below which is a basin some six rods long and four rods wide, bordered by vertical or overhanging walls of rock, about thirty feet high. At its east end this basin is so contracted that for a distance of about twenty feet these walls of rock are only eight to fifteen feet apart. Below, for the next twenty-five rods, the gorge is four to six rods wide, bordered by vertical walls of reddish sandstone or quartzyte, which decline from thirty to twenty and ten feet in hight. The same rock is seen thence nearly all the way for a half mile east, mostly forming cliffs fifteen to twenty feet high at the south side of this creek, to the junction of another stream from the south in section 31, Stately, Brown county, which also has an interesting fall formed by the quartzyte.

The most western exposure of this rock learned of in Cottonwood county is in the N. W. ¼ of section 28, Storden, on land of C. P. Carlson. Typical quartzyte, very compact and tough, varying in color from dull red to slightly reddish gray, is here exposed in the bed of a stream

tributary to Highwater creek, along a distance of fifteen rods or more from north to south, with a width of two to four rods. Its dip is about five degrees to the southeast or S. 60° E. It is much divided by joints and is thereby somewhat fractured into rhomboidal pieces. Ripple-marks were seen in several places, the undulations being two to three inches wide. Fragments of red pipestone up to two inches in diameter occur rarely in this rock.

Another outcrop is reported one mile northeast from the last, on the N. E. ¼ of section 21, Storden, in a ravine; and others occur a half mile southeast of Carlson's, near the center of section 27, in the bed of small ponds through which the brook flows.

The west part of the S. W. ¼ of section 6, Dale, has considerable exposures of quartzyte, scarcely rising, however, above the general surface of the till, along a distance of twenty rods and more from north to south, on a westward slope, about a mile east from the east end of lake Augusta. These ledges are owned and have been slightly quarried by Peter Schmith. The stone varies in color from yellowish gray to a dull red, is much jointed, and has a dip at the quarry of about five degrees northeast. Laminæ of pipestone from a fourth to a third of an inch thick, deep red, traversed by whitish veins, in their predominant red color and soft slaty texture closely like the pipestone of Pipestone quarry, were noted here upon the surface about fifteen feet east of the quarried excavations, occurring at bedding planes along an extent of about two rods. Here, also, fragments of this deep red pipestone, up to one or two inches in diameter, are enclosed in the quartzyte, which is mostly of a more grayish red color.

Several other outcrops of this rock, similar in extent and character, occur within a distance of a mile to the south and southwest through section 7, Dale, and in the east edge of section 12, and perhaps also of section 1, Amo. These most southern exposures of this area of quartzyte were examined by Prof. Winchell in 1873, and have been described on pages 159 and 160 of the second annual report. The dip at one place near the east line of section 12, Amo, is recorded to be "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."

The observations of dip recorded in the foregoing pages indicate that these Potsdam strata in Selma, Delton, Stately and Germantown are monoclinal, dipping generally about five degrees southward; and that probably farther west in Germantown, Amboy, Storden, Dale and Amo, where a greater width is exposed, they are synclinal, on the north dipping about five degrees toward the south, and on the southwest dipping an equal amount toward the northeast and north. From the Little Cottonwood falls in Delton along the distance of three miles northerly to the falls in section 36, Germantown, Prof. Winchell in a recent reconnoissance found numerous outcrops of the rock with a nearly uniform southward dip of about five degrees, from which he computes the thickness of the formation exposed between those points to be approximately 1380 feet. Stratigraphically, the lowest of the beds thus observed are at the falls on Mound creek in Germantown, where outcrops extending twelve hundred feet from north to south, with a dip of five degrees toward the south, give a thickness of 100 feet for the friable sandstone seen at that place. This forms the base of the strata measured, lying below beds of very hard and compact quartzyte, which are almost a quarter of a mile thick.*

*See an instructive paper, by Prof. R. D. Irving, on the nature of the induration of sandstones and quartzytes in Wisconsin, probably of the same kind with the induration of this quartzyte, *American Journal of Science*,(3), vol. xxv, pp. 401-411, June, 1883.

Glacial striæ.]

Fifteen miles south-southwest from the rock outcrops of Dale and Amo, this Potsdam formation is reached in the railroad well at Heron Lake at a depth of 186 feet, its first 34 feet, to a total depth of 220, being a reddish quartzyte or sandstone, underlain by a whitish gray quartzyte. This is the only well in Jackson county which goes through the drift, and no wells were learned of in southern or western Cottonwood county that penetrate to the bed-rock.

It does not seem certain that the Heron Lake well encounters anything but drift deposits above the Potsdam quartzyte; but its section from 115 to 186 feet may be through Cretaceous beds, which, however, were learned of in no other well in these counties. The order of deposits found was soil, 2 feet; yellow till, 13; blue till, 100; yellow clay, 10; dark, very hard and dry, fine silt, like dried mud, 16 feet; light gray clay, free from gravel, 24; and interstratified sand and fine gravel, 21 feet, being in total 186 feet, to the Potsdam rocks before described.

Drift and contour.

The surface of the Potsdam quartzyte in many places shows distinct glacial markings, notes of which are presented in the following table. These bearings are referred to the true meridian, from which the magnetic needle here has a variation of about ten degrees to the east.

Courses of glacial striæ in Cottonwood county.

Selma, N. E. ¼ of sec. 25	S. 20° E.
Selma, S. E. ¼ of sec. 23	S. 20° E.,
and varying from this two or three degrees on each side.	
Delton, S. E. ¼ of sec. 30	S. 15° E.
Delton, S. W. ¼ of sec. 18	S. 15° E.
Delton, N. W. ¼ of sec. 18	S. 25° E.
Delton, N. W. ¼ of sec. 9	mostly S. 25° to 40° E.;
also all courses from S. to S. 80° E., intersecting upon the same surface.	
Amboy, south part of sec. 2, near (north of) a school house..	mostly S. 40° E.;
and, within a distance of one rod from striæ of this course, also	S. 45° and 55° E.
Amboy, S. W. ¼ of sec. 2, at the pipestone locality, about a quarter of a mile northwest from the last	S. 35° to 50° E.,
and rarely deflected to S. 70° E., all intersecting on the same surface.	
Germantown, N. E. ¼ of sec. 36, about thirty rods southwest from the falls	S. 30° E. and S. 70° E. (fig. 35)
Five rods east from the last, striæ were noted at different spots within a space of about one rod square of nearly level rock, bearing	S. 30°, 50° and 70° E.
Generally here these marks have been effaced, and none could be found on the ledge described in the N. W. ¼ of sec. 28, Storden.	
Dale, S. W. ¼ of sec. 6	S. 20° to 25° E.
Dale, south part of sec. 7	S. 34° E.
Amo, east part of sec. 12	S. 30° to 32° E.

Near the Little Cottonwood falls, in the S. E. ¼ of section 8, Delton, and at points on the north side of the quartzyte ridge in the northwest part of this township, the angles of projecting ledges of this rock were observed to be rounded off by glaciation.

The most remarkable deflections and intercrossing of glacial striæ ever seen by the writer, were found at the locality mentioned in the N. W. ¼ of section 9, Delton. It is on the southern slope of the ridge formed by this quartzyte, as already described. This ridge is elevated about 300 feet above the lowland, which, from its base two or three miles farther north, extends northward more than fifty miles, across the basin of the Minnesota river; but its hight above the aver-

age surface to the south and southwest is slight, probably not exceeding 50 feet. Its length is about twenty-five miles, extending from east to west; and this locality is near the middle of its extent. Very distinct glacial markings occur here promiscuously crossing each other in all directions between north to south and S. 60° E., and, very rarely, S. 80° E.; but a great majority are between S. 25° E. and S. 40° E. Many are from ten to thirty feet or more in length, and from an eighth to a half of an inch deep; others are very delicate lines. Curved striæ were observed at one place; two or three parallel furrows (fig. 36), covering a width of several inches and extending about ten feet to the southeast, were gradually deflected nine inches southerly from their direct course in the last four feet. All the other very abundant intercrossed striæ observed here are straight, or deviate only slightly from straight courses. The outcrop containing pipestone in section 2, Amboy, furnished the only similar instance seen in these counties. Here several parallel glacial scratches bend twenty or thirty degrees in a length of about eight inches (fig. 37). The curvature of these ice-marks, where no obstacle existed to cause deflection, indicate that they were engraved during the final melting and recession of the ice-sheet, when it had become thin, and that its margin at the date of this curved striation was near, perhaps within a few rods. In such a situation the unequal melting of the edge of the ice must produce changes, such as are thus recorded, in the direction of its motion.* The prominence of the quartzyte ridge doubtless gave unusual irregularity to the outlines of the retreating ice-border in northern Cottonwood county, which, by the resulting deflections of the glacial current, appears to have been the cause of the singularly varying and intercrossed striation of this region.

During the greater part of the last glacial epoch the ice-fields here appear to have flowed in a nearly south-southeast course; but when they were being melted away, the direction of movement close to the ice-border would be often deflected because it must flow toward the nearest part of this irregular and changing boundary, which here and there became indented by bays of small or large extent. The intersecting striæ on the ledge in section 9, Delton, record very changeable glacial currents, now deflected to a due south course, twenty degrees to the right from the direction which they had previously held through this glacial epoch, but presently diverging as much or twice or three times as much to the left, attaining a southeast or even a nearly east course. The medial moraine directly south of this locality, in Carson and Lakeside, suggests that, when the ice retreated, probably two glacial currents converged here, pushing against each other, and that the striæ bearing south were made by the current on the east, and those bearing S. 60° to 80° E. by the current on the west.

Divergences to the east from the prevailing direction of glaciation were noted also four miles farther northwest, in Amboy and Germantown, upon the northern slope and at the north base of this massive ridge. In Germantown a surface about a yard square was observed, on half of which the striæ bear uniformly S. 30° E., and on the other half S. 70° E., as shown in fig. 35, these portions meeting at a slightly beveled angle from which

*Similar curved striæ are recorded and figured by Desor (Foster and Whitney's *Report on the lake Superior land district*, part I., p. 206), and by Andrews (*Am. Jour. Sci.*(3), vol. xxvi, p. 100, Aug., 1883).

each side slopes down two or three degrees.* The former of these courses of striation is probably that which prevailed till the departure of the ice-sheet, when the great quartzyte ridge and the irregularity of the glacial melting caused a deflection of forty degrees toward the east. The later ice-current was steadily maintained during a considerable time, sufficient for planing off a part of this surface of very hard quartzyte, but not touching the adjoining part, which could only escape by having a thin covering of drift.

FIG. 35. IN THE N. E. ¼ OF SEC. 36, GERMANTOWN.
FIG. 36. IN THE N. W. ¼ OF SEC. 9, DELTON.
FIG. 37. IN THE S. W. ¼ OF SEC. 2, AMBOY.
SKETCHES OF GLACIAL STRIÆ ON THE QUARTZYTE IN COTTONWOOD COUNTY.

The drift spread over Cottonwood and Jackson counties is principally till, in part morainic, being accumulated in knolls and hills, or with a prominently rolling surface in massive, smoothly sloping swells, but for the greater part it is only gently undulating in contour. Its thickness on the quartzyte ridge varies from nothing to probably fifty feet or more, and in other portions of these counties it probably varies from one hundred to two hundred feet in depth. The moraines to be described were formed at the west border of the ice-sheet of the last glacial epoch, the first when this ice covered its maximum area, and the second after it had receded considerably from its farthest limits, when its retreat was interrupted by a halt and perhaps even by some re-advance.

First terminal moraine. The outer or western morainic belt of the Coteau des Prairies extends into the south edge of this state along its course of twenty miles next west of Spirit lake, where the greater part of its width lies in Iowa. From the Little Sioux river at the west side of Minneota, through Sioux Valley and Round Lake townships, to Indian lake in southeastern Nobles county, the part of this formation in Minnesota is characterized by numerous small ridges, hillocks, and swells of till, and is from one and a half to five miles wide, reaching north to Skunk lake, to a half mile beyond Rush lake, to Plum Island and Round lakes, and to the north end of Indian lake. Its greatest extent north in this distance is at the north side of Round lake; but south of this a tract about two miles wide and three miles long to the east from State Line lake, is smooth and only slightly undulating, though enclosed by rolling or knolly morainic areas.

Second terminal moraine. The inner or eastern of the two terminal moraines upon the Coteau des Prairies extends from the west side of Spirit lake north through the central range of townships in Jackson county. The width of this belt is from three to six miles. Its surface is

*Compare similar observations in Rock county, reported in chapter xviii.

prominently rolling, mostly in massive swells, 20 to 40 feet above the depressions, but at many places in small, steep knolls and hillocks of similar hight. The elevation of the range above the general level is from 40 to 75 feet. Its material is till, which here contains more gravel and boulders than on its smooth, slightly undulating areas which extend at each side beyond the limits of the county. In Minneota this morainic belt is about three miles wide, reaching from Little Spirit lake and Clear lakes west to the Little Sioux river. It here has many knolls and short ridges which continue into Hunter, and are crossed seven to ten miles west of Jackson by the road to Worthington. Farther to the north, the moraine forms a prominently rolling tract, about six miles wide, between the Des Moines and Heron lake, rising in smooth massive swells 50 to 75 feet above the general level at the top of the bluffs of the river, and 75 to 100 feet above the lake.

In the southwest part of Cottonwood county, this belt of notably rolling and hilly drift occupies the west half of Great Bend, the north part of Springfield, northeastern South Brook, southwestern Amo, and nearly all of Rose Hill. Its width in these townships varies from two to five miles. To the northwest from the offset of the Des Moines river which crosses this formation in Springfield, it lies a few miles northeast of this river and parallel with it, having within the limits of this county and especially in Rose Hill township a prominently rolling contour in smooth swells, 20 to 40 feet above the intervening hollows and frequent lakes. To the south from this offset and the great bend of the Des Moines, the second terminal moraine lies west of this river and approximately parallel with it, their distance apart being from one to ten or twelve miles, along an extent of a hundred and forty miles, through Jackson county and onward in a nearly south-southeast course to Pilot mound and Mineral ridge in northern Boone county near the center of Iowa.

The most conspicuous portion and most roughly broken contour of this morainic belt in Cottonwood county are in the west part of Great Bend, where a group or range of hills, known as the Blue mounds, begins three miles west of Windom and thence extends three or four miles in a northwest course, with a width varying from a half mile to one and a half miles, lying between the Des Moines river on the northeast and Spring lakes on the southwest. These hills are composed of till with frequent boulders, and rise in very irregular slopes to hights 100 to 175 feet above the river and 25 to 75 feet above the general level at their west side. The most elevated of these mounds, in sections 17 and 20, are visible from the southeast part of Murray county, fifteen miles to the west; but from the east they can only be seen within a distance of six or eight miles.

Medial moraine. Across the Des Moines river, the land ascending from it east of Windom, opposite to the Blue mounds, has similar but less prominent morainic features. It consists of irregular knolls, hillocks, and low ridges of till, with enclosed hollows and lakes, occupying a width of two or three miles, and gradually rising in this distance about 100 feet above the Des Moines river. This tract seems to be part of a medial moraine (so called because formed between opposing ice-currents), connected with the second terminal moraine as a branch from its northeast side, and extending north through the two western ranges of sections in Lakeside and Carson. Its most broken portion is found in sections 17, 8 and 5, Carson, which have many small hills and ridges 40 to 75 feet high, mostly trending from north to south, composed of till with abundant boulders. Ten miles north from these hills in Carson is the morainic tract through which Mound creek flows in Stately, but the intervening area, across which the quartzyte ridge extends from east to west, is destitute of such knolly drift deposits.

East of the second moraine, the country extending from it to the Des Moines river in southern Jackson county is till, nearly flat through the central part of Middletown for five or six miles northeast from Spirit lake; moderately undulating in the eastern third of Minneota; and in the west part of Des Moines township massively rolling, in parallel swells that trend nearly from north to south, sloping gently down on their east and west sides to the intervening depressions which are 30 to 50 feet lower, the distance between the tops of these undulations being from a half mile to one or two miles.

The surface of the part of Jackson county east of the Des Moines river is a smooth, nearly flat, but everywhere more or less undulating sheet of till, sloping eastward ten to twenty feet per mile. Its descent on the line of the Southern Minnesota railroad is 173 feet in eleven and a half miles from the junction of the branch to Jackson, at the top of the eastern bluff of the Des Moines.

Beyond the knolly and broken ascent east from the Des Moines river in the vicinity of Windom, the contour changes to a smooth and nearly flat expanse of till, which thence extends seventy-

five miles eastward, descending with an imperceptible slope to the Blue Earth river, and beyond this rising in the same manner to the belts of drift hills at the sources of the Le Sueur and Cannon rivers, well named by Nicollet "the N. E. prong of the Coteau des Prairies," since they are of the same age with the moraines of these counties and a curved continuation from them (see page 406). The eastern two-thirds of Lakeside and Carson, and all of Mountain Lake township, included in the vast area of intra-morainic till, are slightly undulating and differ only five to ten feet in broad swells and depressions from being a perfect plain. This expanse, stretching on all sides to the horizon, would be commonly called level, but the survey of the Saint Paul & Sioux City railroad shows that its descent eastward is uniformly about twenty feet per mile through these townships, or some 200 feet in the ten miles from the railroad summit a mile west of Bingham Lake to the east line of this county. If the same slope were continued westward it would pass over the summit of the Blue mounds; hence they cannot be seen east of Bingham Lake.

Mountain lake, which has given its name to a railroad station and township, is so called because it contains an island that rises about 35 or 40 feet in steep bluffs, attaining the same hight with the bluffs that surround the lake, even with the average surface of its vicinity. The probable origin of this depression and of its steep enclosing bluffs, has been pointed out in treating of the chains of lakes in Martin county, the most western of which appears to have its beginning in this lake.

West of the second moraine, the eastern shore of Heron lake mainly rises in gradual slopes of till, reaching the summits of the morainic belt at a distance of three or four miles; the south end of this lake, lying within the edge of the moraine, is enclosed by banks about forty feet high; but on the west and southwest is a very flat expanse of till, 10 to 20 feet above the lake, only undulating five to ten feet in slopes a mile long, stretching with slowly increasing hight as far as the view extends westward. On the Sioux City railroad in the ten miles southwest from Heron Lake to Hersey, the ascent is 68 feet; in eight miles on its branch from Heron Lake northwest to Dundee, 26 feet; and on the Southern Minnesota railroad in seven miles northwest from its intersection with the Sioux City line to De Forest, is 32 feet. Trains approaching De Forest from the southeast come into sight near the south end of Heron lake, and are visible during forty minutes before their arrival. This smooth plain of till continues south through Rust and Ewington townships, having the same slight ascent to the west, and crossed from north to south or southeast by occasional water-courses and sloughs ten to twenty feet below the general level.

Interglacial drainage. Heron lake lies in the continuation of the southeast course of the upper Des Moines river below lake Shetek. There seem to be good reasons for believing that lake Shetek, this part of the Des Moines, Heron lake, and Spirit and Okoboji lakes in Iowa, resemble the chains of lakes of Martin county, in occupying portions of what was originally a continuous valley excavated by interglacial drainage in the thick till of the earlier and severer glacial epoch, before the time of the last ice-sheet by which the terminal moraines in this and adjoining states were formed. It is probable that the Des Moines river then continued southeast where Heron lake is now, and onward in the same course through Hunter, where the rolling and hilly drift of the second terminal moraine now forms a watershed a hundred feet above Heron lake; thence southward at the east side of Minneota to Spirit lake and the Okoboji lakes; then, from West Okoboji lake south along the course of the Little Sioux river, which now receives the outflow of these lakes, to its bend three miles east of Spencer; and thence eastward about twenty miles, by Trumbull, Palo Alto and Lost Island lakes, re-entering the present valley of the Des Moines river at Emmettsburg. Hights along this distance are approximately as follows: lake Shetek, about 1,475 feet above the sea; the Des Moines river at its point nearest to Heron lake, about 1,375; Heron lake, 1,403; railroad summit between Heron lake and Jackson, 1,517; Spirit lake, about 1,400; the Okoboji lakes, about four feet lower than Spirit lake; Little Sioux river at Spencer, about 1,300; lakes and lowest part of the divide between Spencer and Emmettsburg, about 1,350; and the Des Moines river at Emmettsburg, about 1,125. The remarkable depth of the south part of West Okoboji lake, exceeding one hundred feet, is thus very probably in an unfilled portion of an interglacial valley, elsewhere choked up with the drift of the later ice-sheet by which the morainic hills and swells, partly rough and partly smooth, adjoining this lake and covering most of northern Dickinson county, in Iowa, were accumulated.

At Emmettsburg this interglacial Des Moines river was joined by a large tributary from the north, formed by the union of the streams whose courses are marked by the chains of lakes in

Martin county, and flowing southwestward across Emmett county at right angles to the present East fork of the Des Moines. Portions of its channel are preserved in Swan lake, six and a half miles long from northeast to southwest, and from one-fourth to two-thirds of a mile wide, only ten to fifteen feet deep, but occupying a hollow twenty-five to fifty feet below the gently undulating expanse of till on both sides; and in the High lakes, nearly three miles long, lying one to three miles south of the soutwest end of Swan lake. This river probably coincided in its course with the present Des Moines southward from the north line of Palo Alto county. Medium lake, which reaches four and a half miles northeast from Emmettsburg, varying from a quarter to a half of a mile in width, mostly ten to fifteen feet deep, with a bottom some forty feet below the average of this moderately undulating region, but at one point, a little north of its center, found to be more than fifty feet deep, its surface being about thirty feet above the Des Moines river, probably marks the position of another interglacial tributary of the Des Moines, joining it at nearly the same place with the branch from Martin county.

Drainage during the last glacial epoch. Very significant changes in the drainage of this region have been produced by the lobe of the ice-sheet which covered these counties and a width of about a hundred miles eastward during the last glacial epoch. From the south end of Heron lake to Okoboji township in southern Dickinson county, Iowa, the interglacial channel of the Des Moines has been principally lost by being filled with the drift of terminal moraines, accumulated at the west border of the ice. The outer belt of these deposits extends in Iowa from Storm Lake in Buena Vista county northward through eastern Clay county to the Okoboji lakes, and thence westward to Ocheyedan mound in Osceola county. Thence passing into Minnesota, it reaches northwesterly through the central part of Nobles county, western Murray county, and the most northeast township of Pipestone county, forming there and farther northwest the highest part of the Coteau des Prairies. The present basin of the Des Moines river from central Iowa northwestward was entirely covered by this ice-sheet; but a small part of its interglacial valley, in southern Dickinson and northern Clay county, Iowa, and most of the basin of Ocheyedan creek, here tributary from the northwest, were outside the ice-lobe, by which they were dammed and their drainage in the old course to the east and southeast was made impossible. A lake about a hundred and fifty feet deep and covering the greater part of Clay county, was thus formed at the west side of the ice-lobe, until its overflow cut the deep, trough-like valley or channel in which the Little Sioux river now flows along the south side of Clay county and in northeastern Cherokee county, 150 to 200 feet deep, and in some places only a quarter of a mile wide between the tops of its bluffs, which consist wholly of glacial drift.* This outlet was so deeply excavated while the ice-sheet lay as a barrier on the east that after its departure the stream continued to flow by this passage to the Missouri, through a broad area of till which has its surface 100 to 150 feet higher than the divide between the Little Sioux and Des Moines rivers east of Spencer.

In northern Clay county, where the Little Sioux river takes the place of the interglacial Des Moines, the broad and deep valley eroded by that stream before the last glacial epoch has become nearly filled with modified drift, which forms an extensive plain, ten miles long and two to four miles wide, bordering the Little Sioux river through Summit, Riverton and Spencer, reaching west to Stony and Ocheyedan creeks. These fluvial beds of gravel and sand were deposited after the excavation of the channel of the Little Sioux river, by which the lake that previously existed here had been drained into the Missouri; and they are thus shown to have been supplied during the latter part of this epoch, while the ice-sheet, in which they had been held, was being melted away.

The decline and departure of this ice was interrupted by a halt and probably by a re-advance, forming a second or inner line of terminal moraine, which reaches through Murray, Cottonwood and Jackson counties, from the east side of lake Shetek southeast to the Blue mounds west of Windom, and thence south to Spirit lake, and continues southeast in Iowa within a few miles west of the Des Moines river to Pilot mound and Mineral ridge. At this time the drainage from the head of the Des Moines basin, in Murray county, and the waters of Heron lake and its tributaries went southward through West Heron Lake, Rust and Sioux Valley townships, and were carried by the Little Sioux to the Missouri river, instead of going southeast as now to the Mississippi. Heron lake then stood about twenty feet higher than now, probably covering three times its present area. The shallow channel of its overflow has become partly filled by the silt of tribu-

*White's *Geology of Iowa*, vol. ii., p. 205.

taries, and contains a succession of sloughs and small reedy lakelets, connected at time of high water by a stream, which is the head and most northern source of the Little Sioux river.

Farther recession of the ice gave to the waters of Heron lake and the upper Des Moines river a lower outlet by the present course northeast across the second terminal moraine at the north side of the Blue mounds, and thence southeasterly along the east side of this moraine. This avenue of drainage became marked by a considerable valley eroded while the ice yet lay as a barrier upon the east part of Cottonwood and Jackson counties; for the top of the bluffs, and the general surface of the country, bordering the Des Moines in eastern Jackson county are slightly higher than the watershed between Heron lake and the Little Sioux river; and, furthermore, the natural slope in eastern Cottonwood and northeastern Jackson county is eastward, so that this river could not flow here to the south-southeast unless its valley had been thus formed before the ice-sheet was melted at its east side, being excavated sufficiently deep to hold the stream afterward in this course.

An exception to the generally smooth contour of the drift-sheet north of the quartzyte ridge is found in a quite roughly hilly morainic area, apparently isolated, which lies mainly in the north half of Stately, the most southwest township of Brown county, and extends into Germantown to the west side of section 12. Its abrupt mounds and ridges of stony till are 25 to 75 feet high, having their greatest prominence in Stately along the lower part of Mound creek. This tract appears to belong to a third terminal moraine.* Through the middle of Germantown a notable valley, having a flat bottom of stratified gravel and sand, enclosed by moderately steep slopes which rise about forty feet to the undulating surface of the till on each side, was observed, extending five or six miles in an east-southeast course from near Dry creek at the north side of section 17 in this township, to Mound creek at the east side of section 30, Stately. Another valley of similar character was noted three-fourths of a mile farther south, running parallel with the last through the north part of sections 25 and 26, Germantown. These deserted water-courses were probably formed during the departure of the last ice-sheet. Upon this region its border doubtless retreated to the north and northeast; and while it still lay as a barrier upon the north part of Germantown and was accumulating the morainic hills that lie a few miles to the northeast in Stately, the drainage from its melting was carried by these valleys southeasterly. Farther northwest, the land for a considerable distance along the probable course of the ice-margin in this stage of its retreat is lower than where these valleys occur, and therefore would be occupied by a lake; and again southeastward, from the south part of Stately to Silver Lake in Martin county, a narrow glacial lake probably extended along the border of the ice-sheet, having a hight about 1200 feet above the sea, and overflowing south of Iowa lake to the East fork of the Des Moines river.

Boulders and pebbles. The boulders of the drift in these counties are mainly granite and syenite, crystalline schists, quartzyte, and limestone. The quartzyte ridge in northern Cottonwood county has supplied from a tenth to a half of the large rock-fragments in the drift south of it. In traveling from Fairmont to Worthington, boulders and pebbles of quartzyte are first seen abundantly in the vicinity of Jackson, and are plentiful thence westward. At the northwest side of Spirit lake this formation has supplied a sixth part of the larger stones and boulders, but its proportion in the beach-gravel is only a fifteenth or twentieth. Of a hundred and fifty small pebbles counted on a space one foot square of the beach at the west side of Spirit lake, half were magnesian limestone, probably derived from the formation that outcrops near Winnipeg; and the other half were

*See page 479; also the report of Brown and Redwood counties.

granite and syenite, schists, white quartz, the red quartzyte, etc. One pebble, two inches long, of pipestone, one of conglomerate, and seven or eight of the ordinary quartzyte, doubtless all derived from the Potsdam formation in Cottonwood county, were included in this number. Among the large boulders, over one foot in diameter, in these counties, it may be that a twentieth part are limestone. At Windom limestone containing *Receptaculites* was found in the drift by Mr. Savidge, in digging his cellar.

Modified drift. The only noteworthy deposits of modified drift observed are the terraces in the Des Moines valley at Jackson, which have been already described on page 496.

Wells in Cottonwood county.

Records of the deposits of drift dug through for wells in Cottonwood county are as follows:

Selma. C. J. Gabrielson; sec. 10: well, 18 feet; soil, 2; yellow till,14; blue till, harder, but spaded, 2 feet; water seeps.

Silas Blackmun; sec. 10: well, 22 feet; soil, 2; yellow till, 16; harder blue till, 4; water rose two and a half feet, in very large supply, from a compact and hard gravelly layer at the bottom.

Mountain Lake. Railroad well: dug 67 feet, and bored 5 feet more, stopped by a boulder; obtaining a fair supply of water, but probably all from the upper part of the well.

Lake hotel; Frank Shaubut, proprietor: well, 64 feet; soil, 2; yellow till, 24; blue till, very hard and compact, 38 feet; water rose from the bottom to stand eight feet below the top in twelve hours. This water was good the first year, but afterward gradually became very offensive to smell and taste, so that the well is no longer used. It has wooden curbing, the decay of which was probably the source of its contamination. Another well, four rods east from the last, found soil 2 feet, and yellow till, 24 feet, from which water seeps in good supply and of excellent quality.

Most of the wells at Mountain Lake village are 15 to 35 feet deep. The yellow till varies in thickness from 15 to 30 feet, succeeded by blue till.

A. L. Warren; sec. 34, about a mile east of the depot: well, 45 feet; soil 2; yellow till, 28; yellowish gray quicksand, 15 feet, not passed through; plenty of water. The only other well in this region that finds this quicksand is a neighbor's, some ten rods south.

Delton. S. M. Beaty; N. W. ¼ of sec. 18: well, 28 feet; soil, 2; yellow till, spaded, 18; Potsdam quartzyte, 8; water came in slowly, and holds through the year ten to fifteen feet deep.

This township has two flowing wells, the only ones learned of in Cottonwood county: Joseph S. Naramore's, in sec. 12, 38 feet deep, which has overflowed six years; and Richard Lahart's well, about 16 feet deep, in sec. 34.

Carson. Arthur Minion; sec. 4: well, 22 feet; soil, 2 feet; yellow till, shaded, 10; blue till, much harder, picked, 10; water rose from sand and gravel fifteen feet in as many minutes. Fragments of lignite are often found in the wells of this region.

Lakeside. Lakeside mill (steam flouring mill), at Bingham Lake: well, 100 feet deep; dug 50 feet and bored below, all in till; has forty feet of water. Other wells at Bingham Lake are 15 to 20 feet deep, with plenty of good water. Stoned wells in this township invariably have good water; but those curbed with wood all become poor because of its decay.

Germantown. Colin Buchanan; sec. 20: well, 23 feet; soil, 1 foot; yellow till, spaded, 20 feet, containing a sandy layer at ten feet, which was one and a half feet thick and dipped 45° to the north; gravel and sand, 2 feet, from which water rose six feet in three hours.

Amboy. Henry Stubb; sec. 24: well, 30 feet; soil, 2; yellow till, spaded, 13 feet, its last five feet being most sandy and gravelly, but also the hardest; blue till, likewise spaded, 15 feet; water rose ten feet in one day from gravel and sand. Several pieces of lignite, up to six inches in length, were found in this well. All the wells in Amboy and Delton have good water.

Dale. J. Q. Picket; sec. 2: well, 20 feet; soil, 2; yellow till, spaded, 18; water rose five feet in one day. The majority of the wells in Dale have excellent water; but some, because of wooden curbing, become too offensive to be used.

Windom. R. R. Jenness; well, 70 feet; soil, 2 feet; coarse gravel with many large boulders, 5 feet; till, yellow at top for a few feet, blue below, very hard, 62 feet; white sand, 1 foot, and extending deeper, from which water rose forty feet in a quarter of an hour.

S. S. Johnson; well, 60 feet; soil, 2; gravel, 4; till, as in Mr. Jenness' well, 54 feet; water rose from sand at the bottom fifty-seven feet in two hours, but afterward fell away by soaking into the ground, and now usually stands ten feet below the surface. At the top of the sand from which the water came, were branches of wood and gasteropod shells, probably interglacial, in a thin layer of muck. The water at first was very dark and disagreeable to the taste, like that of a peat swamp (perhaps because of the decay of wooden curbing); but since the first two years it has been of good quality. Within fifteen rods from this well are others that get a large supply of water in gravel at 12 or 15 feet.

Highwater. G. H. Beng; N. W. ¼ of sec. 23: well, 40; soil, 2; yellow till, becoming dark below, mostly picked, 38; water rose seven feet in a half day, from gravel and sand. This is on a rounded swell, twenty or thirty feet above the country all around for several miles.

R. Hogenson; sec. 30: well, 21 feet; soil, 2; yellow till, spaded, 9; much harder blue till, picked, 10 feet; the only water found seeps into the well at the base of the yellow till. This glacial drift at the depth of eighteen feet contained a piece of lignite, three feet long and nine inches thick, weighing about a hundred pounds. Another lump of lignite, nearly equal in size, has been found within about a mile to the southwest, in the bed of Dutch Charley's creek in section 36, Ann.

C. Peterson; sec. 30: well, 35 feet; soil, 3; yellow till, picked, 17; dark, bluish and brownish till, with irony seams and small pieces of lignite, 15 feet; water rose eight feet in one day from sand and gravel at the bottom, not dug through but found to be at least two feet thick.

Storden. Charles Swenson; sec. 22: well, 20; soil, 2; yellow till, 15; blue till, very hard, 3 feet; water rose five feet from gravel and sand at the bottom.

Charles H. Ripke; N. E. ¼ of sec. 26: well, 16 feet; all yellow till, partly hard and picked; to a layer of gravel, about one foot thick, from which water rose six feet in a half day. All the wells upon this highland, underlain by the red quartzyte, have excellent water.

Ann. Hogen Anderson; S. E. ¼ of sec. 24: well, 18 feet; soil, 2; yellow till, picked, 16 feet; the water seeps.

Rose Hill. Jacob Tabert; sec. 20: well, 42 feet; soil, 2; yellow till, spaded, 32; gravel and sand, 1 foot; blue till, harder than that above, 7 feet, and extending below; water comes sparingly from the gravel and sand, failing in very dry seasons.

Jacob Wall; S. W. ¼ of sec. 28: well, 20; soil, 2; yellow till, 18; water rose eight feet in two hours from sand at the bottom.

Wells in Jackson county.

Wisconsin. John M. Utter; N. W. ¼ of sec. 21: well, 72 feet, the deepest in this township; soil, 2 feet; yellow till, 15 feet; blue till, not harder than the yellow till, but worse to dig, because of its tenacity, 55 feet; water comes slowly from sandy streaks, a half inch to two inches thick, in the blue till, especially in the last twenty feet.

Des Moines. Joseph Thomas; S. E. ¼ of sec. 24, about a mile east of Jackson: well, 33 feet; soil, 2; yellow till, spaded, 10; harder blue till, picked, 21; water rose to ten feet below the top in one day. Wells in this vicinity, on the upland above the Des Moines valley, are 15 to 30, and rarely 50 feet deep, all in till.

Jackson. G. C. Chamberlin: well, 130 feet deep, situated about 30 feet above the Des Moines river, below which it thus goes 100 feet, this, added to the depth of this valley, being about 200 feet below the original surface of the drift-sheet; this well, below its 2 feet of soil, was all till, yellowish above, but mainly bluish, enclosing dark sandy streaks, but no considerable layers of sand or gravel and no water, and having throughout some intermixture of stones and gravel, one boulder weighing about fifty pounds being found at the depth of a hundred feet. Sticks of wood and small gasteropod shells were obtained at about the same depth. This well became filled with surface water, but was not used, and has been filled up. At a point twenty feet from the foregoing, another well has been dug 26 feet deep, in till, mostly yellow but blue below, yielding a plenty of water.

Most of the wells at Jackson find an ample supply of excellent water at depths from 20 to 30 feet.

Delafield. M. A. Foss; sec. 18: well, 22 feet; soil, 2; yellow till, 10; much harder blue till, 10; water rose six feet in three hours, from a vein of sand three inches thick.

Heron Lake. M. A. Foss; at Lakefield, in the S. W. ¼ of sec. 33: well, 21 feet; soil, 2 feet, yellow till, picked, 16; quicksand, 3 feet; water is five feet deep.

Hunter. Railroad well, 68 feet deep; in the N. W. ¼ of sec. 3, one mile east of Lakefield: soil, 2 feet; yellow till, about 20; harder blue till, 18; gray quicksand, 4 feet; blue till, 24 feet, and extending deeper; water came in sandy steaks in the last three feet, and rose in three days to be forty feet deep.

Minneota. William Austin; S. W. ¼ of sec. 25: well, 27 feet; soil, 3; yellow till, spaded, 24; water seeps, filling the well usually to a depth of nine feet.

Weimer. The deep railroad well at Heron Lake, penetrating to the Potsdam sandstone, has been described on page 503. The common wells of Heron Lake are 10 to 20 feet deep, finding 2 to 4 feet of soil, and yellow till, which is spaded, for all below. The water is naturally good, but by the decay of wooden curbing is often made objectionable to both taste and smell.

Sioux Valley. A. McCulla; sec. 34: well, 36 feet; soil, 3; yellow till, picked, 17; sand and gravel, 4 feet; blue till, much harder than the upper till, 12 feet; water rose ten feet in two days from springs in the blue till.

La Crosse. R. Nelson; sec. 13: well, 30 feet; soil, 2; yellow till, 11; yellow "hardpan, almost as hard as rock," 17 feet; water rose five feet from sand at the bottom, but the well is sometimes filled to the top with surface-water.

Ewington. Nelson Jordan; N. W. ¼ of sec. 30: well, 30 feet; soil, 3; yellow till, spaded, 12; darker and harder gray till, picked, 15; water seeps from the lower part of the yellow till, filling the well to a depth of fifteen feet.

Round Lake. J. Walker; sec. 14; well, 19 feet; soil, 2; sand, 4 feet; yellow till, spaded, 8 feet; blue till, very tenaceous, but not harder than the yellow till, 5 feet; water comes in the lower part of the yellow till, usually standing ten feet deep.

The drift contains a considerable proportion of the carbonates of lime and magnesia, giving a very productive soil, and making the water of springs and wells hard; but it supplies no noticeable admixture of the bitter and alkaline ingredients which are found abundantly in the water of some districts farther west.

Analysis of the water of Heron lake.

A sample of the water of Heron lake, collected in June, 1882, was analyzed by Mr. W. A. Noyes, with the following result:*

Chemical series, No. 128. Composition of residue from evaporation.

	Parts per 1,000,000.	Percentage.	Grains per gallon.
Silica	7.1	2.6	0.41414
Alumina and oxide of iron	1.7	0.6	0.09916
Carbonate of lime	102.7	37.7	5.99049
Sulphate of lime	47.9	17.6	2.79241
Nitrate of lime	5.0	1.8	0.29165
Carbonate of magnesia	76.3	28.0	4.45058
Carbonate of lithia	traces.		
Sulphate of potash	8.0	3.0	0.46664
Nitrite of potash	traces.		
Sulphate of soda	18.5	6.8	1.07911
Chloride of sodium	5.1	1.9	0.29748
Total	272.3	100.00	15.88166

*Eleventh annual report.

Iodine, bromine and phosphoric acid, absent Test with potassium permanganate showed 2.6 parts oxygen consumed by organic matter per 1,000,000 water. Hardness, 22 degrees. The water is notable for excessive hardness, due to sulphate of lime and carbonates of lime and magnesia.

Travertine. Small deposits of travertine, or calcareous tufa, made by springs that issue from the drift, often called "petrified moss" from its having incrusted moss and leaves, thereby preserving their forms, occur in Jackson county on the east side of the ravine of a creek near the center of section 26, Petersburg; and on the southeast side of a creek near the center of section 15, Des Moines, about two miles northwest from Jackson and some 50 feet above the Des Moines river.

MATERIAL RESOURCES.

Agriculture must be the chief industry and source of wealth to Cottonwood and Jackson counties. Their soil, their narrow belts of timber beside rivers and lakes, the natural pasturage and plough-land of their broad expanse of prairie, have been treated of on a former page of this report. Items to be noticed here are water-powers, building stone, lime, bricks, and peat.

Water-powers. The only water-power used in Cottonwood county is that of the Windom mills, on the Des Moines river, owned by Collins & Drake; head, nine feet; three run of stone; a large flouring mill.

Another excellent water-power is available on this river a mile below Talcott lake, where a dam may be built which would make this lake a reservoir, raising it three or four feet.

In Jackson county the Des Moines river supplies three powers, all used by flouring mills. These are the Brown brothers' mill, in section 28, Belmont, having a head of about nine feet; the Des Moines Valley mills, owned by E. P. Skinner, in section 10, Des Moines, three miles northwest from Jackson, with a head of about eight feet; and the Jackson mills, at Jackson, owned by J. W. Hunter, with head of nine feet and three run of stone.

Building stone. The Potsdam quartzyte of northern Cottonwood county has been somewhat quarried, as already mentioned, in sections 23 and 25, Selma, in section 8, Delton, and in section 6, Dale. Owing to the very hard and gritty nature of this rock and its tendency to rhomboidal fracture, it supplies only rough blocks, seldom of large dimensions, yet quite suitable for common foundations and walls, and for the masonry of culverts and small bridges.

Lime. Boulders of magnesian limestone, gathered from the drift, are burned for lime by Lars Rasmusson, in section 11, Des Moines, about two

miles north of Jackson. These yield white lime, of which he usually burns two kilns, each containing about a hundred bushels, yearly. It is sold at forty to fifty cents per bushel. Other lime-burners of Jackson county are Andrew Monson, in Belmont, and Ole Solem, in Christiana. No lime is made in other parts of this county nor in Cottonwood county, not because of scarcity of limestone boulders, which are plentiful, but because this region has little timber, fuel being consequently too expensive for this use.

On the southwest side of Spirit lake, white lime is burned from boulders by A. Kingman, who sells it at seventy-five cents per bushel, oak wood being worth $5 per cord.

Bricks. The only brick-making that has been done in these counties is by Major H. F. Bailey, at the west side of the Des Moines river about a quarter of a mile south of Jackson. A kiln of bricks was made here about ten years ago, but none afterward till 1879, when another kiln of 100,000 was burned. These are red bricks of good quality, and are sold for $8 per M. No sand is mixed with the clay, which is dug a few rods northeast from the kiln, at a hight of six to twelve feet above the river. The soil at the surface is removed to a depth of two or three feet, and the next five or six feet are yellow clay, free from gravel, and levelly stratified.

Peat. An exploration of the peat of southern Minnesota was made in 1873 by Prof. Winchell, whose descriptions, in the second annual report of this survey, embrace the following notes pertaining to Cottonwood county.

Mountain Lake. "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 the side of this slough, which is tributary to Mountain lake, the surface quakes and the peat is thickest."

"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." This peat, taken two feet below the surface, analyzed by Prof. S. F. Peckham, was found to contain, when air-dried, 8.69 per cent. of hygrometric water, 31.90 of organic matter, and 59.41 of ash (No. 1).* He estimated a hundred pounds of it to be equivalent to forty-two pounds of oak wood.

Lakeside. "Sec. 24; 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." The analysis of this, by Prof. Peckham, gave 10.80 per cent. of hygrometric water, 16.33 of organic matter, and 72.87 of ash (No. 2); a hundred pounds being equivalent to twenty-one pounds of oak wood.

Peat is again found farther west in the same township, also on "land of S. O. Taggart, 5 miles east of Windom. In a narrow spring ravine, where water stands or slowly runs throughout

*Numbers refer to the table of analyses of these peat ashes, by Prof. Peckham, on page 516.

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."

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

Great Bend. "N. E. ¼ of sec. 38; 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."

"N. E. ¼ of sec. 30; land of Arthur Johnson. Turf-peat occurs in a ravine, twenty feet over, where fuel can be taken out."

Amo. "Sec. 13. 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." This peat, taken two feet below the surface, was found by Prof. Peckham to contain, when air-dried, 9.85 per cent. of water, 42.63 of organic matter, and 47.52 of ash (No. 3); a hundred pounds of it being equivalent to fifty-six pounds of oak wood.

"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." Professor Peckham's analysis of peat taken here two feet below the surface gave 13.58 per cent. of hygrometric water, 53.28 of organic matter, and 33.14 of ash (No. 4); a hundred pounds of this air-dried peat being considered equal in value to seventy pounds of oak wood. Peat from this place three feet below the surface yielded 11.03 per cent. of water, 41.67 of organic matter, and 47.30 of ash (No. 5); a hundred pounds of it being about equivalent to fifty-five pounds of oak wood.

Springfield. "The land of George C. Bush, sec. 6, holds a peaty turf, in a dry slough near the mouth of a ravine, in considerable abundance."

South Brook. "Sec. 2. 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 peaty 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."

"Peat exists, according to Mr. John Crapsey, three miles north of Talcott lake."

Four localities of peat are reported by Prof. Winchell in Jackson county, as follows:

Delafield. "S. W. ¼ of sec. 4; 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. The surface is mostly covered with a short grass, but also with chair-bottom rushes. Some patches also of *Typha latifolia* are seen. No horsetail 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." This peat from eighteen inches below the surface, by Prof. Peckham's analysis, contains, when air-dried, 10.22 per cent. of hygrometric water, 64.48 of organic matter, and 25.30 of ash (No. 6); a hundred pounds of it being worth as much for heating as eighty-five pounds of oak wood.

Weimer. "Sec. 31. 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."

Wisconsin. "On the S. E. ¼ of sec. 27, Mr. W. V. King correctly describes a peat marsh."

Round Lake. "Sec. 20; land of Everett W. Scovill. Peat here covers four or five acres, and is associated with a deposit of bog iron ore."

Analyses of peat ashes.

The ashes of the specimens of peat mentioned as analyzed by Prof. Peckham, were also subjected to analysis by him, and their composition was found to be as follows:

	1.	2.	3.	4.	5.	6.
Silica	64.27	88.28	81.99	72.64	64.37	68.06
Carbon	2.80	1.32	1.14	0.75	0.16	1.34
Iron oxide and iron phosphate	9.75	6.34	9.39	15.46	21.41	8.82
Lime	15.75	0.84	4.84	5.87	6.26	5.03
Magnesia	1.77	0.51	0.60	trace	1.54	4.81
Sulphuric acid	3.69	trace	1.12	5.73	7.58	6.53
Undetermined	1.97	2.71	0.92	....	....	5.41
	100.00	100.00	100.00	100.45	101.32	100.00

Traces of phosphoric acid were found in all; and of alkalies in Nos. 2 and 3. Carbonic acid was present in considerable amount in Nos. 1 and 6, and in very small amount in No. 2.

ABORIGINAL EARTHWORKS.

Though artificial mounds probably exist in these counties, none were observed during their examination.

In the north part of section 17, Spirit Lake, about a mile south of the state line, an interesting group of six or eight mounds, of the usual round form and two to four feet high, was seen beside the road, at the northwest side of Spirit lake and a short distance south of Little Spirit lake, on land fifteen to twenty-five feet above them.

PLATE 21.

GEOLOGICAL AND NATURAL HISTORY
SURVEY OF MINNESOTA

MURRAY AND NOBLES COUNTIES

BY WARREN UPHAM

Explanation.

- Modified Drift, Gravel and Sand
- Till: Smoothly undulating or rolling
- Till: More prominently rolling
- Till: Knolly and hilly } Terminal Moraines

Contour Lines are shown approximately for each 50 feet above the sea.

PLATE 21.

CHAPTER XVII.

THE GEOLOGY OF MURRAY AND NOBLES COUNTIES.

BY WARREN UPHAM.

Situation and area. Murray and Nobles counties (plate-pages 21 and 22) lie in the southwest part of Minnesota, the former being in the second tier of counties north of the Iowa line, from which it is separated by the latter. The east boundary of these counties is 210 miles west from the Mississippi river at La Crosse; their extent from east to west is 30 miles; and from their west boundary to the line between Minnesota and Dakota is 20 miles, this width being occupied by Pipestone and Rock counties. The distance from Minneapolis and Saint Paul southwest to Currie in Murray county, measured in a straight line, is about 140 miles; and to Worthington in Nobles county, about 155 miles.

The most important towns and villages of Murray county are Currie, on the Des Moines river near the foot of Lake Shetek, in Murray township; Avoca in Lime Lake township, and Hadley in Leeds township, on the Black Hills branch of the Chicago, St. Paul, Minneapolis & Omaha railway; and Fulda in Bondin township, on the Southern Minnesota division of the Chicago, Milwaukee & St. Paul railway. The county seat and largest town of Nobles county is Worthington, on the Saint Paul & Sioux City (C., St. P., M. & O.) railway. Hersey and Bigelow are small villages on this line of railroad; and Rushmore and Adrian are considerable towns on its Sioux Falls branch.

Each of these counties is a rectangle thirty miles long from east to west and twenty-four miles wide; so that together their extent from north

to south is forty-eight miles. Murray county has an area of 721.56 square miles, or 461,801.20 acres, of which 16,909.93 acres are covered by water. The area of Nobles county is 727.66 square miles, or 465,704.16 acres, of which 10,827.04 acres are covered by water.

SURFACE FEATURES.

Natural drainage. The Des Moines river rises at the west side of Murray county, and flows east and southeast across this county. Springs and two or three lakelets on the east side of the highest ridge of the Coteau des Prairies, partly lying beyond the west line of Murray county in the east edge of Ætna and Rock townships in Pipestone county, are the heads of the Des Moines river. The greater part of Murray county is drained by this stream. Its most important tributary in this county is the outlet of lake Shetek, which unites with it about a mile west of Currie. The Des Moines river above this affluent is commonly known as Oksida or Beaver creek. About a mile east of Currie, nearly at the center of Murray township, the Des Moines turns southeast, and holds this course to the east line of the county. Its length in Murray county, not including small bends, is forty miles.

The portions of Murray county which lie outside the Des Moines basin, are in its northwest. northeast and southwest corners. At the northwest, the head-stream of Redwood river, rising in Ætna, the northeast township of Pipestone county, flows to the east and north through Ellsborough, receiving the drainage of some thirty square miles in this township. The northwest part of Skandia, the township next to the east, sends its waters into the head-stream of the Cottonwood river.

Holly, the most northeast township of this county, and the northeast half of Shetek township on the west, and of Dovray on the south, and the northeast corner of Des Moines River township, are tributary to the Cottonwood river by Plum creek, and in small part by Dutch Charley's and Highwater creeks.

Southwest of the Des Moines basin, Moulton, nearly all of Chanarambie, and portions of the townships east of these, are drained by the head-streams of Chanarambie and Champepadan creeks, sending their waters into the Rock river, and by that to the Big Sioux and Missouri.

The areas of Murray county thus belonging to four river basins are approximately as follows: within the basin of the Des Moines river, 520 square miles; of the Redwood river, 30 square miles; of the Cottonwood river, 80 square miles; and of the Rock river, 90 square miles.

The most noteworthy *lakes in Murray county* are the following: lake Shetek, the largest, about seven miles long from north to south, and varying from a quarter of a mile to one and a half miles in width, quite irregular in outline with numerous bays and headlands, and containing islands (accidentally omitted from plate 22), its northwestern part being an arm or bay nearly three miles long and an eighth to a third of a mile wide, known as the Inlet; lake Sarah, two miles long from northwest to southeast and about a mile wide, at the center of Lake Sarah township, about two miles west of the Inlet of lake Shetek; lake Maria, extending northwest from lake Sarah, two miles long and a half mile wide; the group of the Bear lakes, four in number, from one mile to two and a half miles in length, lying in the north part of Lowville and the south edge

Natural drainage.]

of Skandia, the most southern of the group being recently called Tibbett's lake; Lime lake, in the township of this name, extending two miles west from Avoca; and Buffalo, Duck and Star lakes and lake Eliza, which with others form a northwest to southeast series, three to four miles northeast from the Des Moines river and approximately parallel with it.

Nobles county is divided to the basins of the Des Moines, Little Sioux and Rock rivers. At the northeast an area of about 240 square miles is drained eastward by Jack and Okabena creeks into Heron lake and the Des Moines river. Elk creek, rising in Elk township, flows east across the south part of Hersey, and joins Okabena creek a short distance after crossing the east line of Nobles county.

The portion tributary to the Little Sioux river and thus to the Missouri, is principally drained by Ocheyedan or Ocheeda creek, and embraces about 90 square miles.

The remainder of this county, including about 390 square miles or slightly more than half its area, is tributary to the Rock river, by Champepadan, Elk and Kanaranzi creeks and the Little Rock river; making, with the tract in the Little Sioux basin, 480 square miles, approximately, drained to the Missouri river.

Lakes in Nobles county. In the western third of Nobles county and thence westward, there are no lakes, or they are very rare and of small area. This region lies on the southwest side of the outer moraine of the last glacial epoch, at which time it lay beyond the boundaries of the ice-fields, though in an earlier cold epoch it was deeply covered by ice and is overspread with its unmodified drift or till. Farther east, this county has frequent lakes. The West and East Graham lakes, respectively two and three miles long, both trending southwesterly, give name to Graham Lakes township; and another township is named from Indian lake, in its sections 27 and 34, about a mile long from north to south, with a maximum depth of fifteen feet. West Okabena lake, nearly two miles long and about a half mile wide, lies at the west side of the town of Worthington. This and the next are not tributary to Okabena creek, from which, however, the West Okabena lake is separated by only a low, marshy tract of small width, and an ice-heaped ridge of gravel and sand along which a road is built; but at its stage of high water in spring this lake has its outlet into the East Okabena lake, of nearly as great area, close east of Worthington, which at such time overflows southward into lake Ocheeda, and through this into Ocheyedan creek. Lake Ocheeda is about six miles long, trending from northeast to southwest, reaching from section 32, Lorain, to the center of Bigelow, with a width that varies from an eighth of a mile or less to a half or two-thirds of a mile. Mr. A. Miner, civil engineer, of Worthington, reports the maximum depth of West Okabena lake to be twenty-five feet; of the East Okabena lake, fifteen feet; and of Lake Ocheeda, in its northeast part, twenty feet. West Okabena lake is estimated to be twelve feet below the railroad at Worthington station, or 1,570 feet above the sea, and this is one foot above East Okabena lake. Lake Ocheeda is estimated by Mr. Miner to be four or five feet lower, being thus 1,565 feet, very nearly, above the sea.

Topography. The Coteau des Prairies in Murray and Nobles counties declines in hight from northwest to southeast. In Nobles county the most elevated portion of this highland reaches from the south and southwest part of Indian Lake township and the east part of Bigelow, north-north-

westerly through the northeast edge of Ransom, southwestern Worthington, the northeast half of Dewald, the southwestern part of Summit Lake, the northeast part of township **103**, range **42**, and through the middle of Willmont.

This crest of the Coteau des Prairies is a belt from three to five miles in width, composed of massive swells and smoothly rounded, moderately sloping hills of till, 30 to 50 and rarely 75 to 100 feet above the intervening hollows. Their trends are more frequently from north to south or southeast than in other directions; but this approach to uniformity in trend is seldom very noticeable, and their order of arrangement and the form and connected outlines of this range of highland show much variety of contour. At a distance of several miles it generally presents the usual aspect of any moderately rolling prairie, appearing to be of about uniform hight; and upon nearer approach, and in crossing this belt, it is seen to consist only of broad and smooth undulations and swells, more or less sculptured, especially on the southwest side, by streams. A branch one to two miles in width, extends from this belt northward through the east part of Summit Lake township, including within its area the lake of this name. Here, and northerly into Murray county, this most prominently rolling and highest part of the Coteau des Prairies in this latitude forms the watershed between the basins of the Mississippi and Missouri rivers. Its connection with the roughly hilly and knolly outer terminal moraine, traced from central Iowa northward to Spirit Lake and thence westerly to Ocheyedan mound, south of this county, and still more prominently exhibited along the crest of the Coteau des Prairies in western Murray county and thence northwesterly to the Head of the Coteau, shows that the border of the ice in the last glacial epoch extended to this belt of massively rolling till; but though it thus represents the outer moraine of that epoch, it nowhere in Nobles county has such roughly broken knolls, and small, short and steep ridges, as are common along nearly all the rest of this morainic line.

Farther westward, the surface of Nobles county is in swells of till, which trend mostly from north to south, more massive and smoother than those which form the outer terminal moraine, and of about the same elevation; or in nearly level, equally high plateaus of till, as at Rushmore, ten miles west of Worthington, and in the southwest part of Little Rock. Northeast from the morainic belt, there is a descent of 50 to 75 feet within one or two miles, and thence a smooth, slightly undulating area of till extends with an imperceptibly descending slope northeastward twenty miles to the inner moraine beyond Heron lake and the upper part of the Des Moines river. The valleys cut by the creeks which cross this expanse are only 10 to 20 feet deep, and the lakes, sloughs and lowest depressions are about the same amount below the highest land of their vicinity to which the ascent from the lake-shores is usually in prolonged, gentle slopes. On the Saint Paul & Sioux City railroad the slope of this broad, approximately flat area of eastern Nobles county is about 100 feet in the eight miles between Worthington and Hersey, thus averaging a descent to the northeast of twelve feet per mile.

In western Murray county the outer or first terminal moraine rises in a conspicuous series of hills, knolls and ridges of till, roughly broken and irregularly grouped, separately of small size and hight, but together forming an elevated belt from 50 to 100 feet or more above the smooth area of till on each side. It includes the west edge of township **105**, range **42**, being here only from one-fourth of a mile to one mile wide; the south two-thirds of Leeds; the northeast two-thirds of Chanarambie, its most conspicuous portion in this county being Buffalo ridge, 100 to 150 feet high, trending from southeast to northwest, in sections 21 and 16 of this township; the west half of Cameron; and the southwest corner of Ellsborough. Its

Topography.]

area in Leeds, extending six miles east from the main course of the series, and surrounded on the south, east and north by a lower expanse of smooth, slightly undulating till, may be a medial branch. The material of this roughly hilly belt is till, but it differs from that of the gently undulating region through which it lies in containing, and being overstrown with, abundant boulders and pebbles, principally of granite, syenite, gneiss and schists, but also including many of limestone. Many of the hollows enclosed among these knolls and ridges are bowl-shaped or of irregular form, without outlet, and occasionally contain sloughs and lakelets.

Moulton, the most southwest township of Murray county, and the west edge of Chanarambie, lie on the west side of this moraine, and have the smooth, massively rolling surface which prevails in the west part of Nobles county, the higher portions of this tract being 50 or 75 feet above the water-courses and twice this amount below Buffalo ridge.

Eight miles northeast from the outer morainic belt, in sections 8 and 5, Mason, is a remarkable plateau of till, with its top nearly level and covering one and a half square miles, from which there is a descent of about 200 feet in three miles east to Lake Shetek, and about 100 feet in the same distance west to Bear lakes. Smooth, prolonged slopes descend from this highland on all sides; and, with the exception of this area, a gently undulating and often nearly flat belt of till, increasing from ten to twenty miles in width, extends from northwest to southeast through the central part of Murray county. Beaver creek crosses this area in a channel usually 20 to 40 feet below the general surface, and the frequent lakes and sloughs lie 15 to 25 feet below the average hight of their vicinity. Avoca and Fulda are situated upon this slightly undulating, approximately flat expanse, with no hills or notable elevations within view, excepting the morainic hills in Leeds, distant ten to fifteen miles westward. Though this region appears to be level, its surface has a somewhat uniformly descending slope of eight or ten feet to the mile from west to east, as shown by railroad surveys. In the distance of about twelve miles from Avoca southeast to Dundee, the descent is 90 feet; and in nine and a half miles easterly from Iona to Fulda the descent is 100 feet, the latter town being 62 feet above De Forest, and 105 feet above the surface of Heron lake, situated respectively six and a half and fifteen miles farther southeast. The Des Moines river, flowing along the east side of this area, has excavated a valley about 75 feet deep, and from a quarter of a mile to one mile wide, to which the descent is mostly by moderate slopes.

In northeastern Murray county the second morainic belt, two to four miles wide, constituting the northeastern border of the Coteau des Prairies extends from lake Eliza northwest by Star, Duck and Buffalo lakes and the northeast side of lake Shetek, occupying the northeast part of Des Moines River township, southwestern Dovray, northeastern Murray, the southwest half of Shetek, and the northeast part of Lake Sarah. It is distinguished from the slightly undulating areas of till at each side by its more frequent boulders and its more rolling and occasionally hilly contour; but it scarcely anywhere exhibits the rough surface which characterizes the greater part of this series of drift accumulations. The summits of its swells are 30 to 40 feet above the intervening depressions, sloughs and lakes; nearly the

same above the general level on each side; and from 75 to 100 feet above the Des Moines river, and 40 to 50 feet above lake Shetek.

The only part of the second moraine in this county which rises in mounds that are conspicuously seen at a distance of several miles, is in the northeast corner of Murray township, upon an area from a half mile to one mile wide, extending two miles northwesterly from Buffalo lake; but its hills here are only 30 to 50 feet above the average hight of the range. Along the northeast side of the northwest arm of lake Shetek, commonly called the Inlet, are frequent small patches where boulders nearly cover the ground, mostly forming knolls from three to five or ten feet high, and occurring from the lake shore to twenty-five feet above it.

The portion of Murray county northeast of this second moraine is drained into the Cottonwood river. It consists of till, with a smoothly undulating or moderately rolling surface, the highest parts being generally 10 to 30 feet above the lowest. The only considerable stream in this northeast corner of the county is Plum creek, which has eroded a remarkable valley, 40 to 50 feet deep bordered by steep bluffs, sloping from 30° to 45°, along a distance of five miles, from the east side of section 18, Holly, to the black walnut grove which borders this stream in the south edge of Redwood county. This valley receives numerous short tributary ravines.

Elevations, St. Paul & Sioux City division, Chicago, St. Paul, Minneapolis & Omaha railway.
From profiles in the office of T. P. Gere, superintendent, St. Paul.

a. Main line.

	Miles from St. Paul.	Feet above the sea.
Hersey (Brewster)	170.0	1485
Elk creek, water	171.5	1473
Summit, grade	178.2	1588
Worthington	178.4	1582
East Okabena lake, water	178.5	1569
Junction of Sioux Falls branch	181.8	1633
Summit, grade	182.3	1654
Summit, grade, highest point on line from St. Paul to Sioux City	184.6	1656
Bigelow	187.8	1631
State line	188.3	1643

b. Black Hills division (Woodstock branch).

Dundee	168.4	1443
Avoca	180.1	1533
Summit, grade	201.1	1850
Summit, grade	201.9	1849
Murray and Pipestone county line, grade	202.5	1839

c. Sioux Falls branch.

Junction	181.8	1633
Summit, grade	184.5	1691
Little Rock river, water	187.4	1629
Little Rock river, bridge	187.4	1649
Rushmore	190.1	1665
Adrian	196.9	1538
Kanaranzi creek, water	198.0	1499
Kanaranzi creek, bridge	198.0	1511
Summit, grade	199.5	1569

Elevations, Southern Minnesota division, Chicago, Milwaukee & St. Paul railway.

	Miles from La Crosse.	Feet above the sea.
De Forest	239.5	1446
Fulda	246.1	1508
Iona	255.6	1608
Summit	259.4	1705
Entering Chanarambie valley	264.0	1634

Elevations. Soil.]

The highest land in Murray county is Buffalo ridge, in Chanarambie township, the top of which is about 1950 feet above the sea. Other portions of the outer terminal moraine, in this and Cameron townships, are from 1800 to 1900 feet in altitude, and it is crossed by the railroad to Woodstock at a hight of 1850 feet. At the northeast corner of Moulton this range is intersected by Chanarambie creek, which is here more than 300 feet below Buffalo ridge. The next six miles of this moraine southward are a comparatively narrow and inconspicuous belt of gravelly and rocky knolls and small ridges of drift, 1700 to 1750 feet above the sea, or 75 to 125 feet above the Chanarambie valley.

Des Moines river has its sources at an elevation of 1800 to 1900 feet above the sea. Lake Shetek, and this river at its outlet, are about 1475; and its point of exit from Murray county is estimated to be about 1400 feet above the sea.

The lowest land of Murray county is the northeast part of Holly, 1250 to 1300 feet above the sea, making the extremes of hight in this county differ by seven hundred feet.

The highest portions of Nobles county, lying in Willmont, in township **103**, range **42**, and in Summit Lake and the north part of Dewald, are 1700 to 1725 feet above the sea. Champepadan and Kanaranzi creeks cross the west line of this county at about 1475 and 1450 feet above the sea. Little Rock river has an elevation of about 1475 feet, and Ocheyedan creek is about 1550 feet above the sea, at the Iowa line. The lowest land in Nobles county is where Jack creek crosses its eastern boundary, at a hight of about 1420 feet above the sea, some three hundred feet below the crests of the morainic belt.

Estimates of the average hights of the townships of Murray county are as follows: Holly, 1400 feet above the sea; Dovray, 1480; Des Moines River, also 1480; Belfast, 1460; Shetek, 1490; Murray, 1525; Lime, 1525; Bondin, 1530; Lake Sarah, 1540; Mason, 1575; Center, 1590; Iona, 1610; Skandia, 1600; Lowville, 1640; Leeds, 1700; T. **105**, R. **42**, 1700 ; Ellsborough, 1725; Cameron, 1775; Chanarambie, 1800; and Moulton, 1660. From these figures the mean elevation of this county is found to be 1590 feet, very nearly, above the sea.

The townships of Nobles county, with estimates of their average hight, are as follows: Graham Lakes, 1460; Hersey, 1500; Lorain, 1560; Indian Lake, 1580; Seward, 1530; Elk, 1575; Worthington, 1625; Bigelow, 1625; Bloom, 1625; Summit Lake, 1660; Dewald, 1660; Ransom, 1600; Willmont, 1700; T. **103**, R. **42**, 1650; Olney, 1580; Little Rock, 1540; Leota, 1640; Lismore, 1600; West Side, 1550; and Grand Prairie, 1500. The mean elevation of Nobles county above the sea, derived from these estimates, is 1588 feet, being almost identical with that similarly obtained for Murray county.

Soil. These counties have nearly the same character as to soil and agricultural value with all southwestern Minnesota, being very fertile and well drained, yielding bountiful harvests of wheat, corn, oats, potatoes, and the small garden fruits, and capable of producing every crop that belongs in this latitude. Stock-raising and dairying are also beginning to be an important part in the resources of the farmers through all this region.

At the surface is a black soil, from one to three feet deep, being usually about two feet, thus colored by vegetable decay, and consequently enriched for the nourishment of the new vegetation of successive years. Otherwise this soil is like the yellow subsoil, both being glacial drift. Everywhere a sufficient proportion of the carbonates of lime and magnesia are present to supply the best conditions for the cultivation of grain, and also to make the water of wells and springs hard; but the sulphate of magnesia, which occasionally appears as a white efflorescence where sloughs have dried up, is yet only a comparatively small ingredient of the soil and very rarely gives any perceptible taste to the water of wells.*

The only areas unsuitable for cultivation are frequent sloughs, valuable for their marsh hay; the steep banks and bluffs of creeks and rivers; and some portions of the morainic belts, which are so knolly and strown with boulders as to forbid ploughing, but are well adapted for pasturage.

Timber and prairie. Neither of these counties has any extensive tracts of timber, which occurs only on the borders of lakes and along the larger streams. In such situations it is wholly or partly protected from the annual prairie fires, and is supplied with sufficient moisture to enable it to maintain an existence. With double the rainfall that this region has, it would probably become covered with timber notwithstanding the partial checks which its spread must sustain from these fires; and with the climate continuing as now, if fires were prevented, a forest would similarly extend itself outward from the lakes and rivers over the whole of this district and of this state.

In Murray county the principal tracts of timber, consisting of elm, bass, bur oak, ash, poplar, cottonwood, wild plum, and other species, are in the space, nearly a mile square, enclosed by the Bear lakes; on the shores of lakes Sarah and Shetek, especially on the northeast side of the latter, in the vicinity of Fremont lake; and along Beaver creek and the Des Moines river. A grove of twenty or thirty acres, now wholly cut for fuel, was found by the first immigrants on the Chanarambie creek, in section 2, Moulton, and was named the "lost timber," because it was the only considerable patch of woodland in that region, the nearest to it being at Bear lakes, ten miles to the north.

Nicollet says of his trip through this county:† "I pitched my tents, during three days, about the group of Shetek or Pelican lakes, that occupy a portion of the space forming the Coteau des Prairies. This name belongs to the language of the Chippewas, and has been given to them by the voyageurs. The Sioux call this group of lakes the *Rabechy*, meaning the place where the pelicans nestle. Their waters are, in a great measure, supplied by a fork from the sources of the Des

*An analysis by Prof. Dodge (Tenth annual report, p. 202) of an "alkali" efflorescence from section 14, Iona, Murray county, showed it to be a hydrous sulphate of magnesia, with slight traces of soda, potash and lime. The proportions of sulphur trioxide and magnesia were the same as in epsomite (Epsom salt), but it had less than half the percentage of water of crystallization required by epsomite.

†*Report on the upper Mississippi river*, 1843; p. 13.

Timber and prairie.]

Moines river. They contain an abundance of fish, and their shores are amply supplied with wood to admit the location of enviable farms. Hence we proceeded to the spot which I have designated on my map as the Great Oasis, and called by the Sioux *Tchan-ptaye-tanka*, translated by the voyageurs *la grande lisiére de bois*—the great skirt of wood" [at Bear lakes]. "This spot is a forest of limited extent, composed of lime trees, swamp ash, prickly ash, white birch, beaver-wood, white oak, etc., and surrounded by large lakes garnished with aquatic plants, swarming with muskrats, covered at certain seasons with wild fowl, and offering a safe protection against the annual firing of the prairies. The usual depth of these lakes is from 7 to 12 feet; and the soil of the borders is found well adapted to the cultivation of the potato, and the growth of culinary vegetables."

Mr. John H. Low enumerates the following species of trees and shrubs found in the woods of Bear lakes: bass, the most abundant tree, 40 to 60 feet high, American or white elm, also 40 to 60 feet high, and sometimes four or five feet in diameter, slippery or red elm, bur oak, white ash, wild plum, willows, climbing bitter-sweet, black raspberry, choke-cherry, prickly ash, black currant, and smooth gooseberry, common; the American aspen, box-elder, cottonwood, hackberry, frost grape, smooth sumach, wolf-berry, red raspberry, thorn, rose and sweet viburnum or sheep-berry, less common.

Nobles county has less timber than Murray, its principal localities being only narrow groves on the edge of the Graham lakes, of the Okabena lakes, of lake Ocheeda, and of Indian and State Line lakes.

Excepting these scanty tracts of wood, both Murray and Nobles counties are altogether prairie, without tree or shrub, none sometimes being within view all around for several miles, but universally covered by a beautiful mat of grass. This is ready for pasturage about the first or the middle of May, and in summer would supply from a half to one ton of hay per acre. Most of the hay gathered by the farmers, however, is from sloughs, which are wet in spring but in summer are usually so hard that horses can be driven over them. Their growth of grass is more than twice as heavy as that of the uplands, but of inferior quality, yielding from two to three tons per acre.

Owing to the scarcity of timber, and the difficulty in the present sparsely settled condition of the country to provide either wood from the Big Woods of central Minnesota or coal from Iowa, a large portion of the immigrants of these counties, probably half of all in southern Murray county, and three-fourths of all in Nobles county, burn hay for their only fuel throughout the year. A few have stoves to which the hay is supplied in a compressed mass, enclosed in a removable fire-box; but mostly it is burned in common coal or wood stoves. The hay used is the most rank growth of the sloughs, three to six feet long, consisting almost wholly of the fresh-water cord-grass (*Spartina cynosuroides*). Large wisps of this are twisted, doubled and tied by hand, being thus brought into compact and convenient form for putting into the stove. One or two of these twisted bunches are supplied every five or ten minutes, and they maintain a hot fire, as serviceable as that of wood or coal. The amount of hay thus used in a year for heating an ordinary room is from eight to twelve tons. An hour's time is sufficient for twisting up a winter day's supply of this fuel. With the more full settlement of this region, some systematic plan may be adopted for securing wood or coal by freight in large amounts and therefore at much lower cost than now, so that their expense will no longer prevent their general use. It also seems quite practicable for farmers to raise all the fire-wood they need by setting out and cultivating ten acres, more or less, of timber. The white willow, cottonwood, soft maple and box-elder are rapid-growing species which thrive well here when protected from the prairie fires. Species should be selected which spring up, like the willows, by new shoots from the stump and roots, when once cut down, so that the tract cut for one year's fuel may grow again and within a few years yield as much more. Allowing an acre of willows for each year, apparently an ample

provision, it seems quite certain that ten acres will be sufficient for the needs of an ordinary household, thus leaving each acre of willows ten years to grow before cutting, in which time they attain a diameter of six to eight inches and a hight of twenty to thirty feet.

The surface of these counties, having for the greater part a smooth, gently undulating or rolling contour, with few or no boulders, presents a vast, fertile expanse, waiting only to be ploughed and sown to yield fifteen to thirty bushels of wheat per acre. Till thus changed into cultivated farms, it annually produces its thin growth of prairie grasses, one to two feet high, which are excellent for pasturage till the first severe frosts, about the middle of September; by which they are whitened and killed to the roots, not continuing green after frosts like the cultivated grasses. Then, after a few days of drying, it is ready to be swept by prairie-fires at any time when they come, until it is covered by the snow of winter; and, should it escape through the autumn, it is again in danger of fires during a month or more in spring, from the departure of the snow until the green grass shoots up anew.

The most abundant species of grass found upon the prairies of this part of Minnesota are as follows: beard-grass (*Andropogon furcatus*, Muhl.), commonly here called "blue-joint," Indian grass (*Chrysopogon nutans*, Benth.), muskit grass (*Bouteloua racemosa*, Lagasca), and porcupine grass (*Stipa spartea*, Trin.), common on land neither very dry nor very moist; another species of beard-grass (*Andropogon scoparius*, Michx.), and a second muskit-grass (*Bouteloua hirsuta*, Lagasca), common on dry swells; the fresh-water cord-grass (*Spartina cynosuroides*, Willd.), in sloughs, making the principal mass of their hay; and rice cut-grass (*Leersia oryzoides*, Swartz), with the last. The prairies also bear a great variety of flowers, including numerous species of aster, golden-rod, sunflower, and blazing-star or button snakeroot, and the rose, lily, harebell, phlox, fringed gentian, and many others.

GEOLOGICAL STRUCTURE.

Glacial and modified drift.

The bed-rocks of Murray and Nobles county have no outcrops, nor are they reached by any wells, so far as learned of in this survey. Drift forms the surface, consisting almost wholly of the unmodified deposit of the ice-sheet, which is called till, boulder-clay, or hardpan. Clay is the principal ingredient, containing always more or less of grit, gravel, and large stones, but boulders exceeding a foot in diameter are usually very rare, so that perhaps in some cases none would be found in ploughing a quarter-section. Though the soil to the depth of a foot or more appears to contain less gravel than the earth excavated in cellars and wells, some intermixture of gravel may nearly everywhere be noticed upon ploughed land; and the true loess, which thinly covers much of Rock county, does not extend east into the counties here described. Under the black soil, the till has a yel-

lowish color to a depth that varies from ten to twenty-five or thirty feet, below which it is dark bluish. Important differences in its hardness are also noted in the sections of deep wells. How thick this drift-sheet is can only be conjectured, since it has not been passed through in these counties; but from what is known of its depth upon other parts of southern and western Minnesota, it is believed to vary from 100 to 200 feet or more in thickness. Here and there this sheet of till encloses layers of sand and gravel, from which comes the large inflow of water often met with in well-digging.

Creeks and rivers have excavated valleys in the drift, the deepest being those of Chanarambie, Champepadan and Kanaranzi creeks, and of the Des Moines river. These eroded valleys are 50 to 75 feet deep and generally a half or three-fourths of a mile wide, bordered by bluffs of moderately steep or sometimes quite abrupt slope. Their bottoms are partly till, like the enclosing bluffs; but much of the lowland adjoining the streams consists of deposits of gravel and sand or fine silt, being part of the alluvium formed during the process of erosion. Its lowest tracts still remain within reach of the high water which is produced by snow-melting in spring or by the largest rains, and these areas of flood-plain are annually increasing in depth by the deposits made during such inundations.

Modified drift, or beds of gravel, sand and clay, whose formation must be referred to glacial conditions, was not observed in these valleys. The only noteworthy deposit of this kind is that found in Grand Prairie, the most southwest township of Nobles county. Here a plain composed of stratified gravel and sand, but covered by a fertile soil, reaches six miles east from Kanaranzi creek, with a width of about four miles, including the southern two-thirds of this township. This nearly level tract is 20 to 40 feet above Kanaranzi creek, to which it supplies a small tributary that has cut a channel of similar depth. The bordering areas of till rise in massive, smooth swells, 40 to 75 feet above this plain.

Terminal moraines. Foregoing descriptions of the surface features of these counties have called attention to the most important distinction in their deposits of glacial drift or till, namely, the existence of two specially rolling and hilly belts, in part very rough and knolly, with an increased proportion, and sometimes an astonishing abundance, of boulders. The

extreme limit reached by the ice in the last glacial epoch is marked by the western of these terminal moraines, which forms the summit of the Coteau des Prairies. This morainic belt is intersected in southern Nobles county by lake Ocheeda and Ocheyedan creek, and in southwestern Murray county by Chanarambie creek. A smooth expanse of till, from ten to twenty-five miles wide, intervenes between this and the eastern moraine, which has a course approximately parallel with the preceding. The second moraine marks the limit of the ice during a pause in its recession, the genial climate before which it had retreated being changed to one of severe cold again, when the ice-border, probably after some re-advance, was maintained steadily at this line during a long time.

In an earlier part of the glacial period a more extensive ice-sheet had overspread all this region, and reached far to the south into Nebraska, Kansas and Missouri, and its thick deposit of till continues beyond the farthest boundary attained by the last ice-sheet. The depth of the drift in the west part of Nobles county and farther westward, outside of these moraines, and certain features of the region included by them, as the remarkable chains of lakes in Martin county, prove that the greater part of the drift in this state was deposited by the ice of this earlier epoch.

Wells in Murray county.

Sections of the drift deposits of Murray county have been observed in well-digging as follows:

Holly. Daniel E. Way; S. W. ¼ of sec. 10: well, 20 feet; soil, 2 feet; yellow till, 17 feet, spaded, except its last five feet which were picked; much harder blue till, 1 foot, and extending lower; water filled the well six feet deep in one day, from a thin gravelly vein at the depth of 14 feet.

Des Moines River. A. H. Twiss; N. E. ¼ of sec. 10: well, 42 feet, dug 32 feet and then bored 10 feet; soil, 2; yellow till, all of it so hard that it had to be picked, containing many small pebbles, but none larger than six inches in diameter, 39 feet; blue till, very tenaceous, but not harder than the yellow till, 1 foot and more. Water rose to six feet below the surface in a half day, and stands there permanently. No layer of gravel or sand was found, and the well continued dry about one day after the boring was finished; then water broke into the well and rose rapidly as stated. This is the greatest thickness of yellow till learned of in Murray county.

Shetek. D. C. Greenman; sec. 20: well, 35 feet; soil, 3 feet; yellowish till, 25 feet; yellowish and darker gray till, interbedded, moister and softer than above, and including sandy streaks, 7 feet; from this lower part of the well water rose ten feet in one day.

D. J. Turner; sec. 26: well, 41 feet; soil, 2; yellow till, 37; harder blue till, 2 feet and reaching lower; water rose nine feet in two hours, and thirty feet, to its permanent level, in the first day, from sandy streaks in the last ten feet.

Murray. F. H. Barrows; sec. 29: well, 18 feet; soil, 2; yellow till, spaded, 16 feet; water comes from sandy streaks, mostly at 12 feet.

At Currie and in its vicinity the wells are from 10 to 20 feet deep, in till. No wood nor shells have been found in well-digging in this region; but small fragments of lignite occur frequently.

Lime Lake. At Avoca the Lincoln hotel has a well 96 feet deep, which was soil, 2 feet;

yellow till, 7 feet; blue till, 85 feet; and gravel, 2 feet, from which water rose to a depth of fifty feet. Most of the wells in this town and its vicinity are only 15 to 20 feet deep, in till like the foregoing, and have a plenty of good water through the whole year.

Bondin. The Fulda town-well, at the center of the village, has a depth of 147 feet. Its section was soil, 3 feet; yellow till, spaded, 32; much harder blue till, picked, 97 feet, containing more stones and gravel than the upper till; then again yellow till at 132 feet and thence 15 feet to the bottom, not apparently distinguishable in composition, color and degree of compactness from the ordinary yellow till of the surface, while its proportion of gravel and pebbles, the largest of which are three or four inches in diameter, appears to be greater; it was underlain by gravel, which yields a very large supply of water, as if from a running stream, as it rises only seven feet. A small piece of wood, seven inches long, resembling red cedar, was found in the blue till at a depth of 67 feet; and a few pieces of lignite, up to two inches in length, occurred at the top of the lower yellow till; but no other fossil remains were found.

The railroad-well at Fulda, about thirty rods southeast from the foregoing, is described by the station-agent to be 115 feet deep, in till, its last 3 feet being a very hard layer, below which the auger dropped nearly a foot; and from this vein water rose seventy feet. This well, however, became so frequently filled with quicksand that it was abandoned; and water is at present pumped for the railroad tank from the north one of the Seven Mile lakes.

Lake Sarah. T. J. Ward; S. E. ¼ of sec. 12: well, 33 feet; soil, 2; yellow till, about 25; blue till, moister and very tenacious, 6 feet; the well was bored, and at this depth was stopped by a boulder; but it is supplied with water which seeps from the yellow till.

Mason. J. M. Denison; N. W. ¼ of sec. 8: well, 20 feet; soil, 2; yellow till, 18 feet, enclosing occasional layers of sand and gravel up to six or eight inches in thickness; water seeps in moderate amount. This is on the south part of a nearly level plateau, much higher than the surrounding country.

Iona. T. Evenson; sec. 14: well, 25 feet; soil, 2; yellowish gray till, 23 feet, spaded; water seeps, usually three to five feet deep.

Lowville. John H. Low; sec. 8: well, 16 feet; soil, 2; yellow till, spaded, with occasional streaks of sand, 14 feet, to very hard blue till below; water seeps, plentiful and good.

Leeds. L. Lukkason; Hadley: well, 40 feet; soil, and yellow till, 15 feet; blue till, 25; both were picked; the only sand found was a thin layer, four to six inches thick, at the depth of 28 feet; water seeps slowly from this, and fills the well to that hight, twelve feet.

T. 105, *R.* 42. Darms & Fenton; N. W. ¼ of sec. 30: well, 14 feet; soil, 2 feet, containing scarcely any gravel; yellow till, picked, quite pebbly, 8 feet; stratified gravel and sand, caving in, 4 feet; the water, of excellent quality, is usually four feet deep, but sometimes fails.

A well dug for the Southern Minnesota railroad on sec. 4 of this township is reported to have gone through till about 220 feet, finding no water; but another well dug near by for this railroad on sec. 5, found at the depth of 15 feet a very large supply of water, enough to fill the railroad tank by rapid pumping without lowering the well.

Cameron. E. Conner; N. W. ¼ of sec. 22: well, 24 feet; soil, 2; yellow till, spaded, 12; blue till, picked, 10; water rose four feet from sand at the bottom. This is at the northeast border of the western moraine.

Moulton. N. M. Williams; sec. 28: well, 16; soil, 2; yellow till, 8; blue till, 6; water seeps, being usually three to six feet deep, of excellent quality, as are all the wells of this region. Fragments of lignite are rarely found.

Wells in Nobles county.

Graham Lakes. Nils Dahl; De Forest, in the west part of sec. 11: well, 25 feet; soil, 2; yellow till, spaded, 19; much harder blue till, picked, 4 feet; water seeps.

J. H. Anscomb; sec. 14: well, 16 feet; soil, 2; yellow till, 14, spaded through its first ten feet, but much harder and picked below; water rose four feet from a gravelly vein at the bottom.

Indian Lake. Charles L. Peterson; S. E. ¼ of sec. 4: well, 22 feet, all till, finding a good supply of water.

Prank Peterson; S. E. ¼ of sec. 16: well, 14 feet; soil, 2; a sandy layer, 1 foot; yellow till, spaded, 11 feet; water seeps, mainly from the sandy layer at the top.

Isaac Horton; sec. 34: well, 35 feet deep; soil, 4 feet; yellow till, spaded, 8 feet; darker, gray

till, marly, very hard, "two to four times as hard to dig as the yellow till," all picked, 23 feet; water rose fifteen feet in three days, from springs in this till at the bottom.

Seward. Frank H. Radant; sec. 4: well, 22 feet; soil, 2; yellow till, 15 feet; much harder blue till, 5 feet, and reaching deeper; water seeps, abundant and good.

Worthington. Peter Tompson; in the town: well, 52 feet; soil, 4; gray till, 8 feet; blue till, 40; water rose suddenly from sand at the bottom to a permanent level twenty feet below the surface. Most of the wells here get an abundant supply of good water at 10 to 20 feet.

Wilson Ager; sec. 30: well, 24 feet; soil, 2; gray till, 18; gray sand, 4 feet; water plentiful, but not rising above the top of the sand.

Bigelow. E. S. Mills; sec. 31, near the village: well, dug 30 feet and bored below to 72 in all; soil, 2 feet; yellowish gray till, 10; blue till thence to the bottom. Several pieces of wood, from two or three inches to one foot long, apparently tamarack, were found in this well, at a depth of 26 feet, in the compact blue till; but no shells, nor other fossils, were learned of in this region.

The railroad well at Bigelow station, 52 feet deep, passing through blue till, is filled with water to twelve feet below the surface.

Bloom. Levi H. Baxter; sec. 24: well, 15 feet; soil, 2; yellow till, spaded, but very hard, 13 feet; water seeps, abundant and of good quality. Wells in this township vary from 10 to 20 feet in depth. Fragments of lignite are rarely found.

Summit Lake. A. Hovey; sec. 8: well, 20; soil, 2; yellow till, 18; water seeps, usually plentiful, but none in very dry seasons.

On Samuel Allen's farm, three-fourths of a mile northwest from the last, a well was dug and bored about 100 feet; finding plenty of water at first, but becoming filled with quicksand.

Dewald. Wells at Rushmore, in the south part of sec. 19, are 12 to 20 feet deep, finding plenty of good water. S. M. Rushmore here has a well 20 feet deep, which was soil, 2 feet, and then yellowish gray till, 18 feet, with water rising from gravel at the bottom and standing about eight feet deep. A boring close by this, at the southeast corner of his store, 60 feet deep, went into blue till at the depth of about 20 feet, and was all blue till below.

A. Roland; S. E. ¼ of sec. 22: well, 16 feet; soil, 2; yellow till for all below; water seeps, scanty. The well at his barn, 24 feet deep, all in yellow till, finds a large supply of water.

Ransom. S. G. Ferrin; S. E. ¼ of sec. 20: well, 22 feet; soil, 2; yellow till, picked, 20 feet; at the depth of ten feet this till contained a layer of water-deposited sand, four inches thick at one side of the well, but thinning out to nothing at the other side; water seeps, and is scanty in a dry season.

Olney. H. M. Ludlow; sec. 22: well, 22 feet; soil, 2; yellow till, 20; water seeps from the lower ten feet, and also comes from a spring in the till at the bottom, standing five to ten feet deep.

In Adrian, at the west side of this township, the Coleman hotel has a well 40 feet deep, the section of which was soil, 2 feet; yellow till, 14; blue till, 24; water rose twenty-seven feet in twelve hours from gravel at the bottom. This is the deepest well at Adrian; others find plenty of water at 15 to 25 feet.

Little Rock. William Wigham; sec. 18: well, 32 feet; soil, 3 feet; yellow till, spaded, but hard, 29; water seeps, mostly from the lower part of the well, abundant and of excellent quality.

W. W. Mallory; S. W. ¼ of sec. 34: well, 33 feet; soil, 3; yellow till, spaded, but hard, 15; much harder blue till, 15 feet and extending lower; water seeps, usually about six feet deep.

Leota. John Loy: sec. 28: well, 26 feet; soil, 2; yellow till, 18 feet; very much harder blue till, 4; sand and gravel, 2 feet, from which water rose six feet.

Lismore. Michael Brown; N. E. ¼ of sec. 21: well, 33 feet; soil, 2; yellow till, 28 feet; exceedingly hard blue till, 3 feet and extending lower; water rose ten feet in four hours, from sandy streaks at the base of the yellow till.

George W. Legros; N. W. ¼ of this sec. 21: well, 23 feet; soil, 2; sandy yellow till, 14 feet; quicksand, 3 feet; very hard blue till, 4 feet and deeper; water, three feet deep. Limy concretions were found in the yellow till.

West Side. Thomas Grace; near the center of this township: well, 62 feet; soil, 2; sand, 12; till, mostly yellow, 48 feet; water seeps, coming in considerable amount at the depth of 54 feet. This is at the top of the west bluff of Kanaranzi creek.

Grand Prairie. Benjamin Midboe; sec 14: well, 18 feet deep; soil, 2; gravel and sand, 16; water abundant and good. This is on the northeast part of a plain which occupies the southern two-thirds of Grand Prairie, having a subsoil of gravel and sand, in which wells go from 12 to 20 feet in depth.

MATERIAL RESOURCES.

The agricultural capabilities of Murray and Nobles counties have been noticed sufficiently on page 523.

No *water-power* is used in Nobles county; and the only one used in Murray county is on the Des Moines river at Currie, where the Lake Shetek mill, employed in the manufacture of flour, and owned by Currie & Crowl, has a head of eight feet. The dam here holds the stream above it level to lake Shetek; and a second dam, situated nearly a mile above this, close below the junction of Bear creek and the outlet of lake Shetek, raises the surface of this lake and creek four feet above the Currie dam, for which it thus forms a reservoir.

The only *stone for masonry* obtainable from these counties is supplied by the boulders of granite, gneiss, limestone, and other kinds, which are contained in the drift. In some localities, as along the bluffs bordering the east branch of Kanaranzi creek four miles northwesterly from Rushmore, in the moraine-like hillocks within a mile west of Adrian, and among the rough drift hills of Leeds and Chanarambie townships in western Murray county, these boulders are abundant up to five feet, and less frequent to ten feet in diameter.

Lime has been burned for the local demand, from drift boulders, in Bigelow and Dewald, Nobles county. The largest limestone block found in this region was on section 25, Dewald, measuring about 20 by 20 by 12 feet in dimensions. It was used for underpinning three houses, besides walling two cellars and three wells. Most of the boulders, whether of limestone, or of the granite and schists, are less than five feet in diameter, and larger ones are rare. Only a twentieth, or less, of the large boulders, but nearly half of the small stones and gravel in the drift, are limestone.

In Murray county, lime is burned by John Swenson, in section 34, Lake Sarah, usually only one kiln yearly.

Brick-making is not undertaken in these counties, because of the high cost of fuel.

Peat. Only scanty deposits of peat are found in this part of the state, and it is very rarely used. Prof. Winchell's report upon the peat of southern Minnesota, from explorations in 1873, mentions four localities in Nobles county, as follows:*

*Second annual report.

Dewald. "Land of B. S. Langdon, sec. 4. 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."

Bigelow. "Peat, eight or ten inches thick, exists on the railroad land, sec. 27, 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."

"At Bigelow, 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."

Indian Lake. "John Haggard takes out turf in a low patch on sec. 4. 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 five or six weeks it is fit for burning. It burns quickly but leaves considerable ash." This peat, according to an analysis by Prof. S. F. Peckham, contains when air-dried 11.93 per cent. of hygroscopic water; 33.48 of organic matter; and 54.59 of ash. A hundred pounds of it are estimated to be equal in value to forty-four pounds of oak wood.

Springs of excellent, cool water issue at many places from the lower part of the bluffs of the Des Moines river, and of Chanarambie, Champepadan and Kanaranzi creeks. On the narrow bottomland of Plum creek, in the N. W. $\frac{1}{4}$ of section 15, and the N. E. $\frac{1}{4}$ of section 16, Holly, the most northeast township of Murray county, are several chalybeate springs, which have formed mounds of ochery mud, one or two feet high, and ten or twenty feet in diameter. Other interesting mineral springs, supposed to be impregnated with both iron and sulphur, occur on the N. E. $\frac{1}{4}$ of section 12, of this township, three miles south of Walnut Grove.

ABORIGINAL EARTHWORKS.

An artificial mound, of the usual rounded form, about fifty feet across and three feet high, lies on the farm of L. Aldrich, close southwest of his house, in the north part of section 7, Murray, at a distance of about forty rods from the southeast shore of lake Shetek. Also, in the south part of the S. W. $\frac{1}{4}$ of section 8, several similar mounds occur, two to three or four feet high; and there are two others in the S. E. $\frac{1}{4}$ of the N. E. $\frac{1}{4}$ of section 18, all these being in Murray township, within two miles northwest from Currie.

North of lake Shetek, two or three of these aboriginal mounds, two to four feet high, were seen upon the top of swells, which rise 30 to 40 feet in hight, east of lake Fremont, and one upon a similar rounded hill west of this lake, these being in the west part of Shetek township.

In Nobles county, such circular mounds, from one and a half to three feet high, are found in the N. W. $\frac{1}{4}$ of section 18, Ransom; and also in the south part of Little Rock.

LINCOLN COUNTY.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

PIPESTONE AND ROCK COUNTIES.

BY N. H. WINCHELL

VICINITY OF THE RED PIPESTONE QUARRY

Explanation

Quaternary — Loess Modified Drift; Till smooth and undulating; Terminal Moraine hilly-Till

Cambrian — Potsdam Quartzyte

Contour Lines are drawn approximately for each 50 feet above the sea.