CHAPTER X.

ARTESIAN AND COMMON WELLS OF THE RED RIVER VALLEY.

On the broad, fertile plain called the Red River Valley, which was the central and deepest portion of the bed of the glacial Lake Agassiz, many artesian wells have been obtained within the thick drift sheet, deriving their supply of water from porous beds or veins of sand and gravel beneath, and frequently between, deposits of bowlder-clay or till. The depths of these wells vary from 40 feet, or rarely less, to about 250 feet, or rarely 300 feet, while a few others penetrate deeper, passing into the underlying Cretaceous beds, or northward into Silurian strata. The height to which the water is capable of rising above the surface of the ground is often only a few feet and seldom more than 25 to 50 feet. Hundreds of these flowing wells, commonly 1 to 2 inches in diameter of pipe, are in use on farms, at grain elevators, and for the supply of towns, on both the Minnesota and North Dakota sides of the Red River. Their distribution and range of depth, both in the United States and in Manitoba, are shown in Pl. XXXVII. Some tracts of considerable area within this valley, however, fail to find artesian water, but even these generally encounter water-bearing layers at depths corresponding with those of the artesian wells, from which water rises nearly to the surface.

Common wells throughout the whole area of Lake Agassiz and upon the adjoining country usually obtain a supply of water sufficient for ordinary farm and domestic uses within depths ranging from 10 feet to 50 feet or occasionally more. But the quality of their water, as also of the artesian wells, is often disagreeable. The fame of the Red River Valley for its large harvests of "No. 1 hard" wheat, averaging 20 bushels to the acre, is nearly equaled by the unenviable reputation of the water supplied by its wells. The drift here contains much of the carbonates and sulphates of lime and magnesia, derived from the Cretaceous strata which

covered this area and were plowed up by the ice-sheet, mixed with much drift from the region of granites, gneiss, and crystalline schists on the northeast, and redeposited as till. The soluble alkaline ingredients of the soil impregnate all the waters of wells, springs, and streams in this region; and in the dry season they are often seen forming a white or gray efflorescence on the surface of the land, resembling frost, sometimes a quarter of an inch thick, being the residue from the evaporation of moisture rising through the porous ground.[1]

Wheat thrives better where the soil contains a considerable proportion of these alkaline salts, so that their presence throughout the Red River Valley is one principal cause of its superiority in wheat raising; and this, grown year after year, gradually takes away these ingredients and prepares the land for other crops. But their effect as dissolved everywhere in wells and streams partly offsets this benefit, and makes the water of all this region objectionably hard, and sometimes in wells and springs noticeably bitter or salt.

The hardness of the water, on account of which it will not dissolve soap, is produced by the carbonates of lime and magnesia, which it has taken up in soaking through the ground. The best way to provide water satisfactory for washing with soap is by collecting the rain from roofs. By the construction of cisterns, this soft water, which also is preferable for drinking and cooking, may be kept constantly on hand, there being generally a good supply of rain in all seasons excepting winter, when it falls as snow.

The water of streams and wells in this district contains a small proportion of the alkaline sulphates of lime, soda, magnesia, and potassa, and carbonate of soda, though not usually enough to be perceptible to the

[1] An analysis, by Prof. James A. Dodge, of an "alkali" efflorescence from a surface of till in Murray County, southwestern Minnesota, 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. (Geol. and Nat. Hist. Survey of Minnesota, Tenth Annual Report, for 1881, p. 202.)

Efflorescent saline matter from one of the alkaline lakes of the Missouri Coteau, analyzed by Dr. G. M. Dawson, contained of sulphate of magnesia, 49.06 per cent; sulphate of soda, 47.73 per cent; and chloride of sodium, 0.75 per cent. A similar saline incrustation from the Souris Valley, examined qualitatively by Dr. Dawson, showed only the magnesic and sodic sulphates. (Geology and Resources of the Forty-ninth Parallel, p. 293.)

taste. These waters, however, more readily than pure water, decompose the wooden curbing, which, being the most convenient and cheapest material, is too commonly used in this region, destitute of stone quarries. The wooden well-curbing, which is commonly pine, soon contaminates the water, and when such wells are left stagnant or only drawn from slightly, the water becomes too foul in smell and taste to be drunk, even by cattle, and it may be the cause of sickness, as intestinal diseases and typhoid fevers, before reaching this stage. Let such wells be pumped so as to fill them with new water every day, and these offensive qualities are principally removed. If bricks, stone, or cement pipe are used for lining wells, and the water in them is frequently renewed by being largely drawn from,

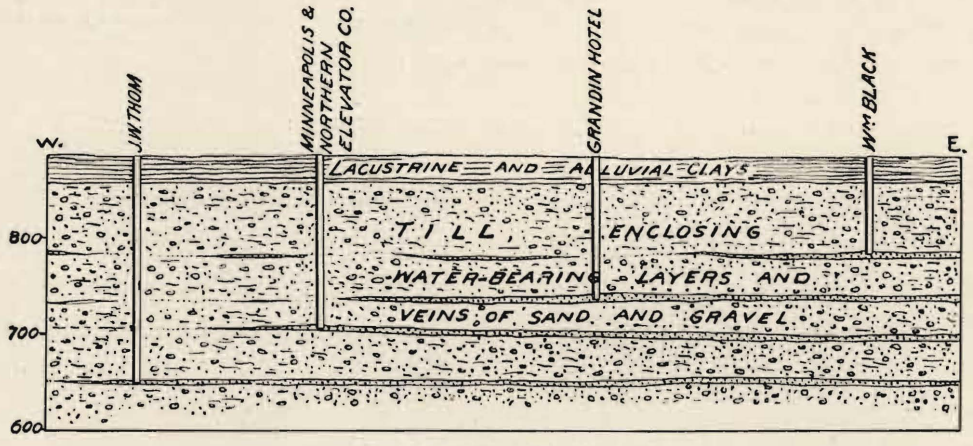

FIG. 31.—Diagram indicating the probable relationship of sources of artesian water at Grandin, N. Dak.

it is generally wholesome and palatable, and is well adapted for nearly all uses, excepting for washing with soap, as before mentioned, and for steam boilers, in which the large amount of scale deposited from it in evaporation is objectionable.[1]

SOURCES OF THE ARTESIAN WATERS.

The narrow areas that may be sometimes occupied by the sand and gravel layers in the drift sheet yielding artesian water, or the thin and in some places entirely deficient condition of these layers, is illustrated by the

[1] See two articles by Prof. N. H. Winchell, on "The water supply of the Red River Valley," Geol. and Nat. Hist. Survey of Minnesota, Sixth Annual Report, for 1877, pp. 9–42, and Ninth Annual Report, for 1880, pp. 166–174.

different depths at which a flow of water was first encountered by four wells in the village of Grandin, N. Dak. These wells, whose probable relationship in their supplies of water may be nearly as shown in fig. 31, are on an area only about 50 rods in extent, and their several depths are 105 feet, 158 feet, 187 feet, and 248 feet. Either the upper water-bearing beds here are narrow, like a stream course, so that they were not found by the deeper wells, or, if they exist as sheets of great width as well as length, they are in some parts thinned out, allowing the impervious till above to rest on that below. The experience in well-boring here is representative of inequalities in depths of flowing wells near together in many other places. More frequently, however, water is obtained from a nearly uniform depth throughout a considerable area, and it is then evidently derived from a single broadly continuous stratum.

FRESH WATER FROM POROUS BEDS OF THE DRIFT SHEET.

Though the water-bearing gravel and sand inclosed between deposits of till often occur in narrow veins or in beds which sometimes thin out, even near where they yield copious artesian flows, they must have a great extent in the direction from which the water supply is received, descending from levels higher than the Red River Valley plain, where the flowing wells are situated. At least, this must be the case where the water is fresh or only very slightly saline, as at Grandin and in all the southern part of the valley as far northward as the vicinity of Crookston, in Minnesota, and Blanchard, in North Dakota, and in a large district of Manitoba, including Winnipeg and the Mennonite reserve east of the Red River.

Upon the higher lands adjoining both sides of this valley the water of rains is partly absorbed by percolation into the drift sheet, chiefly through the most sandy and gravelly layers. Thence it passes in these porous veins and beds downward to the valley plain, where it is heavily pressed by the head of water filling their upper portions. When a boring penetrates the impervious overlying beds of alluvial and lacustrine clay and of till the water usually rises with a strong flow above the surface (fig. 32). If the height and pressure of its head are inadequate for this, it rises in the

pipe to a permanent level, below which in most cases it can not be lowered by pumping, as a continual supply is received from the distant portions of the subterranean reservoir.

SALINE AND ALKALINE WATER FROM THE DAKOTA SANDSTONE.

North of Crookston and Blanchard to the international boundary and in the south edge of Manitoba the water of the artesian wells, almost without exception, tastes distinctly saline and alkaline. It seems very probable

FIG. 32.—Section across the Red River Valley, showing the water supply of its fresh artesian wells. Horizontal scale, 15 miles to an inch.

that the water-bearing beds of that large portion of the Red River Valley differ widely in the origin of their water supply from the foregoing. Instead of deriving their water, like the fresh artesian wells, from rainfall upon higher parts of the drift surface contiguous to the Red River Valley, there seem to be good reasons for believing that the brackish water is mainly

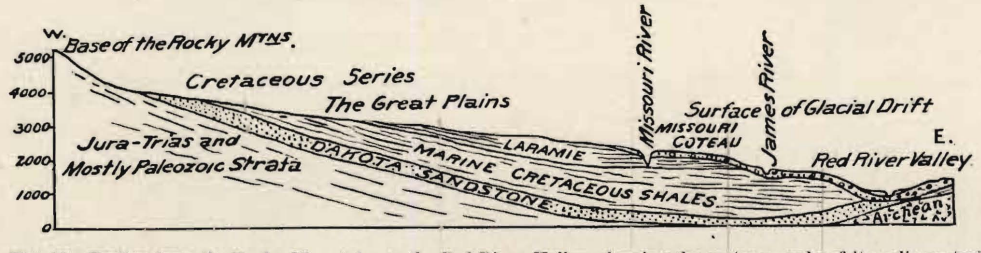

FIG. 33.—Section from the Rocky Mountains to the Red River Valley, showing the water supply of its saline artesian wells. Horizontal scale, 150 miles to an inch.

from the Dakota sandstone, which forms the base of the Cretaceous series in the upper Missouri, Assiniboine, and Saskatchewan basins, coming through that sandstone from its outcrops on the flanks of the Rocky Mountains and Black Hills, and permeating upward into the drift of the Red River Valley from areas where this sandstone is the underlying bed-rock (fig. 33). That the saline artesian waters found within the basin of Lake Agassiz

come from these distant sources is indicated by the artesian wells obtained farther west in North and South Dakota, which also need to be somewhat particularly described here, since they are intimately related with the saline springs and flowing wells of the Red River Valley.

Relationship to the artesian wells of Devils Lake and the James River Valley.—Deep artesian wells of somewhat saline and alkaline water, like that of the part of the Red River Valley just described, are obtained on a belt that extends across North and South Dakota from Devils Lake to Yankton and Vermillion, including the greater part of the James River basin. Wherever borings along this belt have penetrated to the Dakota sandstone, the lowest Cretaceous formation in the upper Missouri region, artesian water has been found. Probably as many as 200 wells have been bored, their depths ranging from 900 to 1,550 feet, except in the southern part of the James and Vermillion valleys, where many wells are only 600 to 750 feet deep, and a few, the farthest southeast, are between 300 and 400 feet in depth. These wells are mostly 5 or 6 inches in diameter, and their strong pressure, commonly from 50 to 175 pounds per square inch at the surface, makes them valuable not only for fire hydrants but also to furnish power for manufacturing purposes. Several wells have been bored at Aberdeen, and five years ago fifteen wells were in use in Yankton. The pressure of the wells in Yankton is sufficient to raise the water 129 feet, and in numerous places along the middle portion of the James River Valley, as Huron, Redfield, and Aberdeen, the pressure corresponds to a rise of more than 400 feet above the surface.

The sections of these deep wells in North Dakota and on the high land between the James and Missouri rivers in South Dakota include, beneath the drift, the Fort Pierre, Niobrara, and Fort Benton divisions of the Cretaceous series; but along the lower part of the James River and on the Vermillion erosion during the Tertiary era removed the upper portion of these beds, leaving only the Fort Benton shales or a part of that formation over the Dakota sandstone.

At Devils Lake, where an artesian well was bored in 1889, about 6 feet above the depot, or 1,470 feet above the sea, the section was as follows:

Section of well at Devils Lake.

	Feet.
Glacial drift, till as on the surface	25
Dark shale, nearly alike through its whole thickness, including the Fort Pierre and Fort Benton formations, with no noticeable calcareous beds at the intermediate Niobrara horizon	1,403
Gravel, of granitic pebbles up to a half inch in diameter, firmly cemented with nodular pyrite	3
Dakota sandstone, or rather a bed of loose sand, very fine, white, or light gray, the base of which was not reached	80
Total	1,511

From the sandstone, at the depth of 1,470 feet, brackish artesian water came up with a rush, but sand soon filled the pipe so that the supply became small. It is from this level that the present flow comes, through narrow slits cut in the pipe. The boring was continued 40 feet deeper, but no such strong flow was obtained below. In July, 1889, when the well was completed, it supplied 1,800 barrels of water in twenty-four hours, or about 40 gallons per minute, the diameter of the pipe being 8 inches, reduced to 3½ in the lower portion. The stream flowing away was then turbid with the exceedingly fine particles of sand brought up from the bottom.

The Jamestown well, bored in the winter of 1886–87, about 8 feet below the depot, or 1,400 feet above the sea, went through a similar section of about 1,400 feet of shales, with no distinctly different portion to indicate the place of the Niobrara formation.

At Deloraine, in Manitoba, 1,644 feet above the sea, situated close northwest of the Turtle Mountain and about 100 miles northwest from the city of Devils Lake, an unsuccessful boring for an artesian well has found, under a thickness of 94 feet of glacial drift, a somewhat uniform section of shales, largely calcareous in their lower half, extending to the total depth of 1,800 feet, according to Mr. J. B. Tyrrell, of the Geological Survey of Canada.[1] At that depth, which was bored during the years 1888 to 1890, the top of the Dakota sandstone had not been reached, so that it is known to be at least nearly 200 feet lower than at Devils Lake and more than 156 feet below the sea-level.

[1] Trans., Roy. Soc. Canada, Vol. IX, Sec. IV, 1891, pp. 91–97.

Artesian wells deriving water from the Dakota sandstone in North and South Dakota.

Locality.	Distance on latitude and longitude from the southeast corner of South Dakota.		Depth.	Pressure at surface per square inch.	Head above surface, computed from pressure.	Altitudes above the sea.		
	North.	West.				Source of water in upper part of the Dakota sandstone.	Surface, railroad at station.	Head, computed from pressure.
	Miles.	*Miles.*	*Feet.*	*Pounds.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Devils Lake	390	119	1,511	.....	.....	0	1,464	.....
Jamestown	305	110	1,476	95	219	—76	1,408	1,619
Oakes	252	80	944	.....	.....	378	1,322	.....
Ellendale	243	101	1,087	125	288	362	1,449	1,737
Britton	228	72	1,004	.....	.....	350	1,354	.....
Columbia	216	92	965	175	404	339	1,304	1,708
Andover	202	72	1,070	90	208	406	1,476	1,684
Groton	204	82	960	[1]187	432	344	1,304	1,736
Aberdeen	206	101	908	175	404	392	1,300	1,704
Ipswich	204	127	1,270	70	162	260	1,530	1,692
Mellette	186	101	900	.....	.....	400	1,300	.....
Ashton	174	101	915	[1]50	115	381	1,296	1,411
Doland	167	81	950	.....	.....	405	1,355	.....
Redfield	166	103	900	175	404	395	1,295	1,699
Faulkton	176	132	1,210	.....	.....	363	1,573	.....
Hitchcock	148	97	950	175	404	389	1,339	1,743
Huron	130	88	863	175	404	424	1,287	1,691
Miller	140	126	1,148	125	288	439	1,587	1,875
Highmore	141	148	1,552	25	58	338	1,890	1,948
Harold	141	163	1,453	80	185	348	1,801	1,986
Woonsocket	108	91	750	153	353	558	1,308	1,661
Letcher	97	85	600	.....	.....	700	1,300	.....
Mitchell	84	79	600	.....	.....	701	1,301	.....
Plankinton	85	102	750	140	323	778	1,528	1,851
Kimball	87	126	1,068	95	219	720	1,788	2,007
Vermillion	20	24	365	15	35	785	1,150	1,185
Meckling	23	31	338	.....	.....	818	1,156	.....
Yankton	27	46	610	56	129	586	1,196	1,325
Tyndall	34	71	730	.....	.....	688	.....	.....
Fort Randall	38	106	600	45	104	660	[2]1,260	1,364

[1] The pressure reported at Ashton is 100 or 125 pounds less than would be expected in proportion with other localities, and at Groton it is somewhat more. The discrepancy of the latter, however, is no greater than may be due to the superior permeability of the water-bearing stratum.

[2] Approximate altitude of high water of the Missouri River at Fort Randall.

For the greater part of my notes of the artesian wells of South Dakota, also of Ellendale and Oakes, in North Dakota, I am indebted to "Resources of Dakota," published by the Territorial commissioner of immigration in 1887, and to recent correspondence with Prof. G. E. Culver, then of the University of South Dakota, and with Prof. C. W. Hall, of the University of Minnesota. These data, with those obtained by me at Devils Lake and Jamestown, I have placed in tabular form for convenient comparison, showing (1 and 2) the distances of the localities north and

west from the mouth of the Big Sioux River at the southeast corner of South Dakota; (3) depths of the wells; (4) their pressure at the surface, wherever it has been obtainable, in pounds per square inch; (5) the corresponding height or head to which the water would rise above the surface; (6) the altitude, with reference to the sea-level, of the source of the artesian water in the Dakota sandstone; (7) the altitude of the surface; and (8) the height of the computed head of water above the sea.

The flow of water from the Dakota sandstone at Devils Lake is found exactly at the sea-level, but the top of the sandstone formation is 39 feet higher. At Jamestown the flow rises from a depth of 76 feet below the sea-level, indicating that the top of the Dakota sandstone there sinks slightly lower than at Devils Lake. Along the distance of 85 miles from north to south between these points its level is probably nearly constant, and borings at intervening towns, as New Rockford and Carrington, will doubtless find artesian water at or slightly below the sea-level. Farther south the top of the sandstone and its water supply are found throughout a large district of South Dakota and the south edge of North Dakota at a plane from 250 to 450 feet above the sea. Continuing still southward, from Woonsocket to the Missouri River the water-bearing stratum rises to altitudes from 558 to 818 feet above the sea, the highest levels being at Meckling and Vermillion, the most southeastern localities of this list.

The same southeastward ascent of the Dakota sandstone reaches to its outcrops on the southwest side of the Missouri in Dakota County, Nebr., whence its name is derived, opposite to the southeast corner of South Dakota. There, and at other extensive outcrops in western Iowa and eastern Nebraska, having approximately the same elevations as the surface at Vermillion and Yankton, the water coursing through this sandstone finds outlet in springs; and these avenues of discharge explain the gradual reduction in the altitude of the head of water above the sea-level as the series of wells is followed from north to south and from west to east. Somewhat uniform altitudes of 1,619 to 1,743 feet are recorded as the heights to which water would rise in pipes for all the wells where pressure is reported, from Jamestown to Huron and Woonsocket, excepting those west of Huron, which will be considered later, and the well at Ashton,

where the reported pressure is probably erroneous, lacking 100 pounds or more of its true amount. At Hitchcock the head of water has a computed altitude of 1,743 feet above the sea; 18 miles to the south, at Huron, it is 1,691 feet; 22 miles farther south, at Woonsocket, it is 1,661 feet; and 81 miles still farther south, at Yankton, it is only 1,325 feet. Fig. 34 illus-

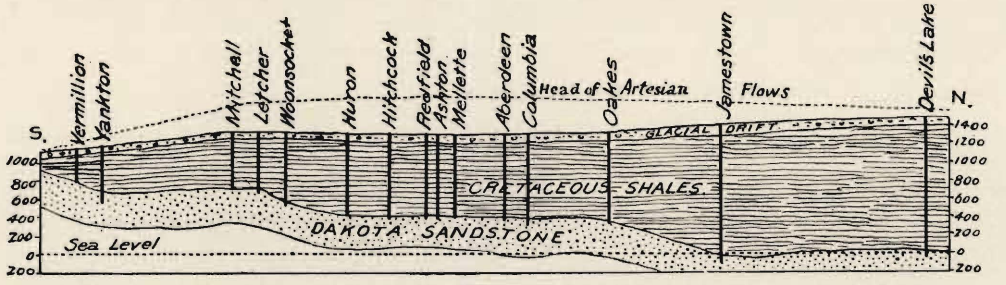

FIG. 34.—Section showing the series of artesian wells from Devils Lake and Jamestown southward to Yankton and Vermillion. Horizontal scale, 75 miles to an inch.

trates this relationship of the series of artesian wells extending from north to south in the James River Valley.

Equally distinct gradients of the plane of water head are found descending from west to east on and near the latitudes of Huron and Yankton. Thus at Harold, 75 miles west of Huron, the head is 1,986 feet above the sea; at Highmore, 15 miles east of Harold, it is 1,948 feet; at Miller it

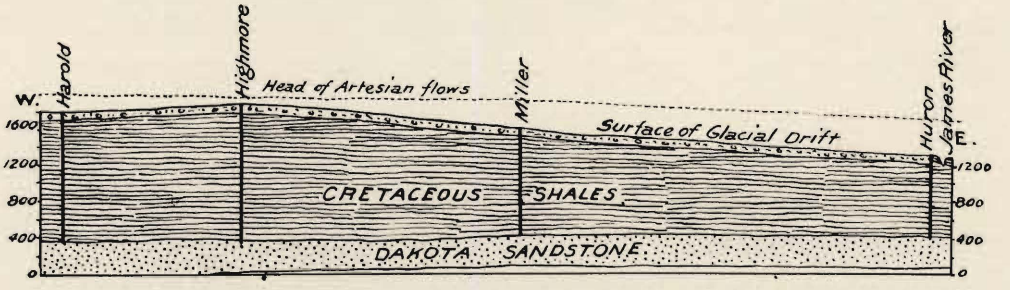

FIG. 35.—Section showing the series of artesian wells from Harold eastward to Huron. Horizontal scale, 15 miles to an inch.

has declined 73 feet in a distance of 22 miles farther to the east; and in the 38 miles thence to Huron it falls 184 feet more. The relationship of the wells at these places is shown in Fig. 35. From Kimball to Plankinton, in 24 miles from west to east, the water head declines 156 feet. Between Fort Randall and Yankton, in a distance of 60 miles from west to east, this plane

descends at least 40 feet, but the descent is more if the well at Fort Randall is at a considerable height above the Missouri River. In 25 miles from Tyndall eastward to Yankton, the water head sinks probably 150 or 200 feet. In the next 22 miles eastward to Vermillion the descent is 140 feet. This feature of the artesian water supply is caused, as before stated, by its outlets through springs in outcrops of the Dakota sandstone, which begin 30 to 40 miles southeast of Vermillion and extend thence southeast and south.

All the eastern outcrops of the Dakota sandstone are lower than the upper portions of the James River basin and the wells farther west at Highmore and Harold. These outcrops, therefore, can not be the sources from which the sandstone receives its artesian water, but, as we have seen, they are the avenues of its natural outflow. We must look instead to the western outcrops of this formation, where it skirts the Black Hills and exposes its upturned edges along the base of the Rocky Mountain ranges, for the areas upon which the water is carried downward into the sandstone. Thence we know this stratum to be continuous beneath the plains to the James River Valley, for there are no nearer or other inlets from which the copious supply of the artesian wells can come. At a plane of similar or greater depth an artesian reservoir exists beneath much, if not all, of the country westward to the mountains. The gradients of the altitudes to which the water of wells is capable of rising along east-to-west lines in South Dakota, as at Huron, Miller, and Highmore, are approximately the same as the average westward ascent of the country, demonstrating this western origin of the water supply, and indicating that such wells may be obtained upon an extensive region of the arid plains.

The quantities of alkaline matter and salt dissolved in the water of these wells usually give it a brackish taste, and make it unfit for drinking by people and for ordinary domestic uses; but it is drunk freely by cattle and horses, with no unfavorable effects. These mineral ingredients seem to have been derived from the Cretaceous shales, and probably in part from beds in the Dakota formation, with which the water has been in contact during its slow percolation hundreds of miles through the sandstone. They are the same in kind and similar in amount with the mineral matter of Devils

Lake, concentrated by evaporation without outlet from the water of inflowing streams and springs, which bring very small amounts of these salts dissolved from the drift and Cretaceous shale of the adjoining country.

Much shale gravel and detritus, rich in sulphates, are present in the glacial drift over nearly the entire Red River basin, and the percolating rain water found by the fresh artesian wells in the drift of the southern and northern ends of the Red River Valley has acquired minute quantities of alkaline and saline matter. But where its proportion is large, as in the brackish water of the wells from Crookston and Blanchard northward to the edge of Manitoba, it seems impossible that so remarkable difference can be due to diversity in the material of the drift, or to longer time and better opportunity afforded to the water for such impregnation while percolating through porous beds or veins in the drift. The saline and alkaline artesian waters of the drift gravel and sand along this central portion of the Red River Valley therefore appear to be received mainly from the same Dakota sandstone which supplies the deep wells of the James River Valley.

Several wells in the vicinity of Casselton, Blanchard, and Mayville, ranging from 317 to 404 feet in depth, pass through the drift and enter a very fine white sandstone, probably the Dakota formation, from which they obtain flows of brackish water. About a dozen miles east of Blanchard the drift was found to have a total thickness of 310 feet, below which a boring went 107 feet into exceedingly fine white sandstone, finding, however, no artesian water, apparently because of the very close texture of the rock. The top of the sandstone in these wells is 650 to 575 feet above the sea. If it is the Dakota sandstone, as seems probable and nearly certain, it has an ascent of about 600 feet in 75 miles east from the meridian of Devils Lake and Jamestown, rising in its approach toward the Silurian, Cambrian, and Archean areas of Minnesota and Manitoba. Along a line about 13 miles north of the international boundary the top of the Dakota sandstone ascends eastward from a depth at Deloraine exceeding 156 feet below the sea-level to a depth of only 320 feet below the surface at Morden, where it is encountered 658 feet above the sea.[1] The Dakota sandstone

[1] J. B. Tyrrell, "Three deep wells in Manitoba," Trans., Roy. Soc. Canada, Vol. IX, Sec. IV, 1891, pp. 91–104.

there rises more than 800 feet in a distance of 106 miles from west to east. It appears thus to be the bed rock, on which the drift is deposited, beneath extensive tracts in the middle part and on the western border of the Red River Valley, discharging there its alkaline and saline artesian water into the permeable beds of gravel and sand in the drift sheet, whence it rises in the brackish wells of that district.

Relationship to artesian wells at Tower City and Grafton, N. Dak., Humboldt, Minn., and Morden (not artesian) and Rosenfeld, Manitoba.—An artesian well at Tower City, 50 miles east of Jamestown, is 4 feet lower than the depot, being 1,168 feet above the sea. Its depth is 670 feet, through drift, 163 feet; Cretaceous shales, with occasional beds of sandstone, 502 feet; and quicksand, into which the boring advanced only 5 feet. Salty and alkaline water outflows 9½ gallons per minute, and is capable of rising 33 feet above the surface. The scanty flow and low head of this well suggest that the water-bearing stratum may be inclosed within the Fort Benton shales; but its altitude, 500 feet above the sea-level, accords with that of the sandstone reached by wells at Blanchard and Mayville, so that more probably it is the top of the Dakota formation. The plane of the head of water supplied from this formation would show a marked descent northeastward, as is thus indicated at Tower City, still more distinctly at Morden (page 81), and in less degree at Devils Lake, in comparison with Jamestown and Ellendale, if there are abundant natural outlets of this artesian water along the Red River Valley, as appears to be true, by springs rising through the drift. These brackish springs occur on many of the streams tributary to the Red River both in North Dakota and Minnesota, the most remarkable being on Forest and Park rivers, which therefore were formerly called the Big and Little Salt rivers.[1]

Beneath the central part and western side of the Red River Valley, the Dakota sandstone, forming the base of the great Cretaceous series which is penetrated by the wells at Deloraine, Devils Lake, and Jamestown, probably abuts in many places, with horizontal or only slightly inclined stratification, upon the eroded western edges of the similarly almost horizontally bedded Silurian rocks. Undoubtedly a part of the salt contained

[1]Translations of their Ojibway names, according to Rev. J. A. Gilfillan, Fifteenth Annual Report, Geol. and Nat. Hist. Survey of Minnesota, for 1886, p. 463.

in the water of the artesian wells in the drift of the Red River Valley, as well as of its saline springs, has been supplied directly from the underlying Silurian formations, which, as stated in Chapter III, yield an artesian flow of brackish water at Grafton, N. Dak, and flows of rather strong brine at Humboldt, Minn., and Rosenfeld, Manitoba. The relationship of these rocks to the adjacent Dakota sandstone suggests a question whether possibly some of the salt in the water of this sandstone at Morden, Tower City, Devils Lake, and along the James River Valley may have come from the same source. The gradients of the head of the artesian wells of North and South Dakota show, however, by their descent toward the east and southeast, that the currents of water running through the Dakota sandstone come from the Rocky Mountains and Black Hills, and that they find egress by springs in the Red River Valley and in the valley of the Missouri southeast of Yankton. On account of the greater weight of saline than of fresh water, this subterranean drainage of the vast western plains may have contributed much to the quantity and strength of the brine contained in the deep reservoir of the Silurian strata beneath the bed of Lake Agassiz. It seems to me, therefore, more likely that the Dakota sandstone has been chiefly a giver rather than a recipient of salt, in its relation to the Silurian formations penetrated by the Humboldt and Rosenfeld wells.

ANALYSES OF WATERS FROM WELLS, STREAMS, AND LAKES IN THE RED RIVER VALLEY AND THE ADJOINING REGION.

The following analyses show the composition of the mineral matter which had been held in solution and was left after evaporation by the waters of several wells, streams, and lakes in this region. The first column in each analysis gives the proportion of the several ingredients to the weight of the natural water in parts per million. In the second column their percentages are stated, and the third notes the weight of each in grains per standard gallon of the United States, containing 231 cubic inches. Nos. 1, 3 to 7, and 10 to 12 were analyzed under the direction of Prof. James A. Dodge, of the University of Minnesota, by his assistants,

Mr. C. F. Sidener[1] and Prof. William A. Noyes.[2] No. 2 was analyzed by Mr. G. Christian Hoffman,[3] and Nos. 8 and 9 by Mr. Frank D. Adams,[4] of the Geological Survey of Canada. The hardness of these waters, when noted, is in degrees of Wanklyn's scale.

1. Brine from the artesian well at Humboldt, Minn. (pages 74–76).

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	208.5	0.4	12.15
Alumina	40.9	0.1	2.38
Carbonate of iron	18.5	.....	1.08
Sulphate of lime	1,990.2	3.5	116.08
Sulphate of magnesia	1,236.4	2.1	71.12
Carbonate of magnesia	1,347.5	2.4	78.60
Chloride of magnesium	1,567.6	2.7	91.44
Chloride of calcium	2,684.0	4.7	156.55
Chloride of potassium	724.3	1.3	42.26
Chloride of sodium	47,402.5	82.8	2,764.99
Phosphoric acid	Traces.	.....	.....
Total	57,220.4	100.0	3,336.65

The proportion of common salt in the total dissolved solids of this water is 82.8 per cent, or about five-sixths. "This gives it," as Prof. N. H. Winchell remarks, "more than the average per cent of chloride of sodium found in the Michigan brines, while the total solid matter in solution is only from one-third to one-half as much."[5]

[1] Geol. and Nat. Hist. Survey of Minnesota, Thirteenth Annual Report, pp. 43, 98, 101, 102 (Nos. 1, 10, and 11); and Fourteenth Annual Report, p. 345 (No. 4). Am. Geologist, Vol. VI, p. 218 (No. 3).

[2] Geol. and Nat. Hist. Survey of Minnesota, Eleventh Annual Report, pp. 172–175 (Nos. 5, 6, 7, and 12).

[3] Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. I, pp. 13–15 M.

[4] Ibid., Report of Progress for 1878–79, pp. 8–11 H. (Reduced to refer to United States standard gallon. Compare pp. 7–12 C.)

[5] Geol. and Nat. Hist. Survey of Minnesota, Thirteenth Annual Report, p. 43.

2. Brine from the artesian well at Rosenfeld, Manitoba (pages 78–80).

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	12.6	.....	0.73
Carbonate of iron	Traces.	.....	.....
Carbonate of lime	77.7	0.2	4.53
Sulphate of lime	4,151.1	9.6	242.05
Borate of soda	Traces.	.....	.....
Chloride of magnesium	1,722.5	4.0	100.44
Chloride of calcium	398.2	0.9	23.22
Chloride of potassium	417.9	1.0	24.37
Chloride of sodium	36,497.1	84.3	2,128.15
Total	43,277.1	100.0	2,523.49

Bromine and iodine are both present, the former apparently exceeding the latter. The proportion of magnesium assumed to be in combination with them as bromide and iodide amounts to 59.6 parts per million. This brine is slightly purer than that of the Humboldt well, but its content of salt is one-fourth less.

3. Water from the artesian well at Jamestown, N. Dak. (page 529).

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	35.7	1.6	2.0823
Alumina	3.5	0.2	.2041
Carbonate of iron	2.2	0.1	.1283
Carbonate of lime	188.0	8.5	10.6743
Sulphate of lime	249.0	11.2	14.5241
Sulphate of magnesia	154.2	6.9	8.9944
Sulphate of soda	1,139.4	51.2	66.3602
Sulphate of potash	81.5	3.7	4.7523
Chloride of sodium	369.1	16.6	21.5296
Phosphates	Traces.	.....	.....
Total	2,222.6	100.0	129.2496

Hardness of this water, 21 degrees. In the test for the amount of its dissolved organic matter, by Tidy's permanganate method, the oxygen consumed in three hours was 0.7 part per million.

The water of the Jamestown well tastes strongly brackish, and is representative of many of the wells of the James River Valley deriving their supply from the Dakota sandstone; but some are less brackish and even palatable, while some others are more saline. According to Prof. Henry Montgomery, of the University of North Dakota, the water of the artesian well at Devils Lake (page 529) contains approximately 0.25 per cent of chloride of sodium (common salt), as compared with the whole weight of the water, or seven times more than the Jamestown water; and about 0.37 per cent of sulphate of soda (Glauber's salt), or nearly three and a half times more than is shown in the foregoing analysis.

4. Water from the Miniwaste artesian well, Browns Valley, Minn. (page 89).

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	13.0	0.5	0.7583
Alumina	0.4	.....	.0233
Protoxide of iron	0.7	.....	.0408
Sulphate of lime	51.8	2.1	3.0215
Sulphate of magnesia	27.9	1.1	1.6270
Sulphate of soda	1,452.6	59.0	84.7302
Phosphate of lime	5.0	0.2	.2916
Chloride of sodium	912.7	37.1	53.2378
Chloride of potassium	Traces.	.....	.....
Carbonic acid	Traces.	.....	.....
Nitrates	Traces.	.....	.....
Total	2,464.1	100.0	143.7305

The test for organic matter, with permanganate of potash, showed 1.63 parts oxygen consumed per million. This water has a considerable reputation for its aperient and alterative medicinal properties. Its content of Glauber's salt is about one-fourth more than in the water of Jamestown, and it has two and a half times as much common salt.

5. Water from an artesian well at Carman, Polk County, Minn.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	26.2	5.7	1.529
Alumina and oxide of iron	1.5	0.3	.087
Carbonate of lime	88.6	19.4	5.171
Carbonate of magnesia	52.9	11.6	3.087
Carbonate of lithia	Traces.		
Carbonate of potash	11.5	2.5	.671
Nitrate of potash	Traces.		
Carbonate of soda	73.8	16.2	4.308
Sulphate of soda	47.5	10.1	2.773
Borax	Traces.		
Chloride of sodium	156.5	34.2	9.134
Bromide of potassium	Traces.		
Iodide of potassium	Traces.		
Total	458.5	100.0	26.760

Nitrates, absent; phosphates, absent. The test with permanganate showed 0.85 parts oxygen consumed by organic matter per 1,000,000 water. Hardness, 12.5 degrees. This well is less saline and alkaline than many others on both sides of the Red River thence northward to the international boundary; but it is more so than most of the artesian wells southward in this valley.

6. Water from the Red River at Fergus Falls, Minn.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	14.3	7.0	0.83412
Alumina and oxide of iron	1.2	0.6	.06999
Carbonate of lime	101.0	50.0	5.89133
Carbonate of magnesia	71.4	35.4	4.16476
Carbonate of lithia	Traces.		
Carbonate of potash	4.2	2.1	.24919
Bromide of potassium	Traces.		
Nitrate of potash	Traces.		
Nitrite of potash	Traces.		
Carbonate of soda	5.8	2.8	.33831
Sulphate of soda	1.8	0.9	.10499
Chloride of sodium	2.3	1.2	.13456
Total	202.0	100.0	11.78725

Iodine, absent; phosphoric acid, traces. The permanganate test showed 1.4 parts oxygen consumed by organic matter per 1,000,000 water. Hardness, 9.5 degrees.

7. Water from the Red River at St. Vincent, Minn.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	13.0	4.6	0.75829
Oxide of iron and alumina	1.0	0.4	.05833
Carbonate of lime	97.8	34.3	5.70467
Sulphate of lime	35.7	12.6	2.08238
Nitrate of lime	1.1	0.4	.06416
Carbonate of magnesia	81.9	28.7	4.77723
Phosphate of lithia	0.6	0.2	.03499
Sulphate of potash	8.7	3.1	.50747
Nitrite of potash	Traces.		
Bromide of potassium	Traces.		
Sulphate of soda	21.7	7.6	1.26576
Chloride of sodium	22.9	8.1	1.33576
Total	284.4	100.0	16.58904

Iodine, absent. In the permanganate test the oxygen required for oxidation was 3.5 per million. Hardness, 19 degrees.

8. Water from the Red River one-fourth of a mile above the mouth of the Assiniboine.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Carbonate of lime	105.6	20.4	6.155
Carbonate of magnesia	154.3	29.8	8.996
Sulphate of lime	96.3	18.6	5.614
Sulphate of potash	14.5	2.8	.846
Sulphate of soda	67.4	13.0	3.938
Chloride of sodium	79.9	15.4	4.656
Total	518.0	100.0	30.205

The hardness of this water is 23.9 degrees.

9. Water from the Assiniboine River one-fourth of a mile above its junction with the Red River

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Carbonate of lime	173.0	35.4	10.090
Carbonate of magnesia	137.7	28.2	8.027
Sulphate of potash	13.2	2.7	.769
Sulphate of soda	117.4	24.1	6.845
Chloride of sodium	46.8	9.6	2.730
Total	488.1	100.0	28.461

The hardness of this water was 20.6 degrees, being slightly less, like its total content of mineral matter, than in the water of the Red River at the confluence of the Assiniboine. The stage of rivers, whether in partial flood or at the low level of seasons of drought, decides to a large extent whether their dissolved ingredients are little or much. The amount of clayey mud and fine sand borne along mechanically suspended in the water of rivers is vastly increased by their rise and stronger currents in times of floods; but the amount of matter dissolved in the water, which is the only portion considered in these analyses, is then much less than at their lowest stages, when they hold little or no mud in suspension.

Although in the waters of the last two analyses the Red River had more dissolved matter, both mineral and organic, than the Assiniboine, the average proportion of the latter throughout the year is probably the greater. Samples of water from these streams, similarly collected by Dr. Robert Bell and analyzed by Dr. Baker Edwards, showed only about two-thirds as much of both mineral and organic matter in the Red River as in the Assiniboine.[1] These samples were collected October 18, 1873, and those of analyses 8 and 9 were taken on October 26, 1879. Recent rains in larger amount on one of these basins than on the other, or differences in their volume due to lack of rainfall, probably account for these different results of the analyses.

[1]Geol. and Nat. Hist. Survey of Canada, Report of Progress for 1878–79, pp. 7–12 C.

10. Water from Big Stone Lake.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	106.50	19.2	6.2090
Carbonate of iron	2.20	0.4	.1283
Carbonate of lime	110.50	20.0	6.4455
Carbonate of magnesia	63.00	11.4	3.6748
Sulphate of magnesia	148.05	26.7	8.6358
Sulphate of potash	12.48	2.3	.7280
Sulphate of soda	95.63	17.3	5.5781
Chloride of sodium	15.12	2.7	.8819
Phosphates	Traces.	.....	.....
Total	553.48	100.0	32.2814

Oxygen consumed by organic matter in the permanganate test, 1.32 parts per million. This water is remarkable for its large proportion of silica.

11. Water from the Mississippi River at Brainerd, Minn.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	18.2	9.3	1.0616
Alumina	3.9	2.0	.2275
Carbonate of iron	4.2	2.2	.2453
Carbonate of lime	111.1	57.1	6.4787
Carbonate of magnesia	27.7	14.2	1.6169
Carbonate of potash	6.0	3.1	.3499
Carbonate of soda	19.4	9.9	1.1292
Sulphate of soda	3.0	1.5	.1749
Chloride of sodium	1.5	0.7	.0875
Nitrates	Traces.	.....	.....
Phosphates	[1]	.....	.....
Total	195.0	100.0	11.3715

[1] Slight traces.

Oxygen required for the oxidation of organic matter by the permanganate test, 1.28 parts per million.

12. Water from Lake Superior, collected at Grand Marais, Minn.

Ingredients dissolved in the water.	Parts per million.	Percentage.	Grains per gallon.
Silica	0.5	1.1	0.02917
Alumina and oxide of iron	Traces.		
Carbonate of lime	30.8	67.4	1.79656
Carbonate of magnesia	9.1	19.9	.53080
Carbonate of lithia	Traces.		
Carbonate of potash	1.9	4.2	.11083
Nitrate of potash	0.2	0.5	.01167
Nitrite of potash	[1]		
Carbonate of soda	0.5	1.1	.02917
Sulphate of soda	0.6	1.3	.03499
Chloride of sodium	2.1	4.5	.12249
Total	45.7	100.0	2.66568

[1] Minute traces.

Iodine and bromine, absent; phosphates and borates, absent. The test with permanganate showed 0.35 parts oxygen consumed by organic matter per 1,000,000 water.

Hardness, 3.5 degrees, so low amount being less than the average of "soft" well and spring waters.

This analysis of the very pure water of Lake Superior (perhaps even more remarkable for its small content of organic than of mineral matter) is presented for comparison with the waters of the Red River Valley. It contains less than one-fourth as much mineral matter, and only slightly more than this proportion of organic matter, as compared with the water of the Upper Mississippi River at Brainerd. These proportions, in comparison with the water of Big Stone Lake, are respectively one-twelfth and about one-fourth. The Red River at Fergus Falls has about four and a half times as much mineral matter as Lake Superior, and four times as much organic matter; but at St. Vincent these proportions are increased respectively to 6 and 10, and the former is still further raised to 11 at the mouth of the Assiniboine and the city of Winnipeg.

The artesian water at Carman has ten times as much mineral matter and two and a half times as much organic matter as Lake Superior, and these proportions for the Jamestown artesian well are respectively about

49 and 2. But a far greater contrast is afforded by the water of the Humboldt artesian well, which contains about 1,250 times more dissolved mineral matter than Lake Superior, while the ratio of their salinity is 22,572 to 1.

It should be remarked, however, that these comparisons are made with one of the purest lakes of the world. Few analyses of the natural waters of lakes and streams show so little dissolved mineral and organic matter. Reindeer Lake, lying in the great Archean area of central Canada, north of Lake Winnipeg, is one of these, for it has only about three-fifths as much dissolved matter as Lake Superior; and an equally small amount, or even slightly less, is found in the waters of Bala Lake, in Wales, and Loch Katrine, in Scotland.[1]

USE OF ARTESIAN WATER FOR IRRIGATION.

Within the agricultural eastern half of both North and South Dakota, occasional years, and sometimes two or three years in succession, have much less rainfall than the average. These years of drought and consequent complete or partial failure of crops have been exceedingly discouraging to the people of these States, checking the immigration which poured in rapidly during a series of comparatively wet years, with magnificent crops, from 1880 to 1885. The great fertility of the soil, however, when supplied with sufficient moisture, causes the questions to be asked: Can artificial irrigation be provided during seasons of drought on this area? and, Can artesian wells be profitably used for this purpose?

These questions are not of so great importance for the Red River Valley, where no drought has severely affected the crops during the fifteen or twenty years since the earliest settlement and development of farming, as for the closely adjacent country on the west, from the vicinity of Devils Lake southward along the Sheyenne and James rivers, where many farmers sowing 50 to 200 acres or more in wheat harvested little or nothing during the very dry years of 1887 to 1889. But within the Red River Valley portions of the summers of these and other years have been so dry that artificial irrigation would have benefited the grain fields. In a few instances

[1] Geol. and Nat. Hist. Survey of Canada, Report of Progress for 1880–81–82, pp. 6, 7 H.

and on a small scale the water of artesian wells in this valley has been applied to patches of garden vegetables and other crops near dwellings.

Will it be profitable, on a larger scale, to store the water of artesian wells in reservoirs for use in the season of growing crops, and especially during severe droughts? To this inquiry we may reply by computing the amount of water needed for irrigating a given space, as a quarter-section of 160 acres, the usual area of a homestead. Allowing a depth of 12 inches of water for this use during the growing season, the year's supply of water from a well flowing 100 gallons per minute is required, without allowance being made for leakage or evaporation from the reservoir. The Devils Lake well would, therefore, irrigate only 64 acres, and the Jamestown well, flowing 375 gallons per minute, will water less than a section 1 mile square. But each of these wells cost about $7,000, to which must be added the cost of the construction of reservoirs and irrigating ditches, placing the expense of such water supply far beyond its prospective value for ordinary agriculture.

Unusual difficulties were encountered in boring these wells, which are the deepest, excepting only the well at Highmore, in the list on page 530. With the experience now acquired, they might probably be bored for half as great expense; and shallower wells, from 600 to 1,000 feet deep, as at Yankton, Woonsocket, and Aberdeen, may be bored and piped at a cost ranging from $800 to $1,500. The still shallower artesian wells in the drift of the Red River Valley, varying in depth from 35 feet to 250 or 300 feet, cost from $50 to $200 or $300. Each of these wells could supply water sufficient for the irrigation of a few acres, and those having the most copious flow would irrigate 50 acres or more if their water were stored in reservoirs for use only during the summer.

An important objection, however, against the use of this water for irrigation seems to lie in its dissolved alkaline and saline matter, which must be left in the soil. After continued use during many years, the residuum from the water would quite certainly prove injurious to crops, so that the land would become worthless. Such results have attended irrigation with only very slightly saline water on the alluvial plains of the arid northwestern provinces of India. The proportion of sulphate of soda in

streams flowing down from the Himalayan range and in canals taking water from them varies from 9 to 43 parts in a million, and the proportion of common salt is from 0.23 to 15 parts; yet under the dry climate of northwestern India the natural evaporation of so nearly pure water, and its use in irrigation, have caused extensive tracts of land formerly productive to become barren.[1]

Neither the water of the Red River at St. Vincent nor that of the very slightly brackish artesian well at Carman is more suitable for irrigation than the Himalayan waters mentioned; while the bitter water of the Jamestown and Devils Lake artesian wells, on account of its larger content of common salt and of Glauber's and Epsom salts (sulphates of soda and of magnesia), would be far worse for the land, in which saline and alkaline matter would be accumulated by the evaporation of the water.

Concerning the results following the use of artesian water for irrigation in the Red River Valley, Prof. C. W. Hall, of the University of Minnesota, writes me as follows, under date of January 14, 1891:

> Officers of our agricultural experiment station say that in the Red River Valley experiments already show that ground watered from artesian wells is, after three or four years, almost wholly unsuited to raising the current crops. Several large farmers in that region have sunk wells to secure a supply of water for gardens, and have found that very soon their garden patches must be moved to other places.

In many portions of the great arid region of the western plains and the Cordilleran mountain belt sufficiently pure water for irrigation is furnished by streams, especially where they flow from neighboring mountains, and less frequently by artesian wells. But it must be reluctantly said that within the agricultural area of Lake Agassiz, and upon the adjoining district of North and South Dakota, neither the rivers nor artesian wells can supply water well adapted for application to the land during a long series of years. Fortunately, irrigation is not greatly needed in any part of this lacustrine area; and on the adjoining region the bountiful harvests of the years of copious rainfall may fully offset the occasional failure of crops.[2]

[1] Medlicott and Blanford, Manual of the Geology of India, pp. 413–415.

[2] See Report of the Special Committee of the United States Senate on the Irrigation and Reclamation of Arid Lands, four volumes (bound in two), Washington, 1890.

NOTES OF ARTESIAN AND COMMON WELLS.

The following notes present many sections, showing in detail the character and order of the drift deposits penetrated by artesian and common wells in the Red River Valley and on the contiguous higher eastern and western borders of Lake Agassiz. A few of these wells pass through the drift and afford information of the underlying Cretaceous and Lower Silurian strata. Among the many records of wells gathered during the survey of the shore-lines of Lake Agassiz, this list selects in general the most noteworthy, as those remarkable for their depth, for abundant flow or sudden rise of water, or for their sections of the drift and older formations. At the same time the ordinary or average depth, or the range in depth of other wells, and the quantity and quality of their water supply, are often stated, with the prevailing character of the drift, lacustrine, and alluvial beds.

Two classes of wells, peculiar respectively to the beach ridges and the deltas, may be here described once for all, so that no examples of them will appear in the following pages. Many farmers, in selecting the site for their dwellings, have wisely placed them on the beautifully rounded, wave-like ridges of gravel and sand which mark the former shores of Lake Agassiz. Their houses have dry cellars, and their wells, after passing 10 to 15 feet through the gravel of the beach to the underlying till, usually obtain an ample supply of excellent water, healthful for people, horses, and cattle to drink. The water is hard, or unfit for washing with soap, because of the presence of the carbonates of lime and magnesia dissolved from the gravel, sand, and till; but it is usually free from alkaline matter, such as is often contained in the water of this district when it has percolated through the till and its inclosed sand and gravel beds for longer distances.

On the deltas of Lake Agassiz wells also usually have water of the same good quality, but it is found at a greater depth. Usually on these tracts the depth to water ranges from 20 to 50 feet; but on the Pembina delta and near the outer border of the Assiniboine delta a thickness exceeding 100 feet in their porous sand and gravel deposits must be penetrated before the plane of saturation or of water running through their basal portion is reached. Along the foot of the frontal slope of the delta, or

on the banks of the river which has cut through it, this water issues in large springs.

The deepest well of this class noted was on the Pembina delta, close north of the river, in the northeast quarter of section 36, township 163, range 57, where T. R. McLaughlin had dug 145 feet and bored 30 feet farther, in all 175 feet, not yet obtaining any water. The material of the section was all water-deposited sand and gravel, some layers having pebbles as large as 3 or 4 inches in diameter, but mostly sand. A well only a half mile to the north, on the same delta, has a good supply of water at the depth of 30 feet, and in some places springs issue only halfway down the bluffs inclosing the Pembina River, which flows some 225 feet below the delta plateau upon which these wells are situated. Here and there somewhat clayey layers in the delta, or otherwise comparatively impervious beds, cause water to be found by wells before reaching the bottom of the sand or the general plane of its saturation. More frequently wells must go to that plane, lying in the Pembina delta mostly at a great depth, as exemplified also by the wells mentioned on page 359.

The arrangement of these notes is in three divisions, under the States of Minnesota and North Dakota and the Province of Manitoba. In each of the two States the counties are taken separately, in their order from south to north. In each county the geographic order of the townships whose wells are described is from south to north, and secondarily from east to west; and in any township where several wells are noted they are given in the numerical order of the sections (as shown on page 11).

It has been found most convenient to note in the same list both the artesian and the common wells. The artesian water often flows only to the surface or a few feet above it; and many other wells obtain water which rises from a deep source to within a few feet below the surface, coming evidently from the same beds that elsewhere supply the flowing wells. Among the common wells of less depth and not so nearly related with the artesian, the water often, and, indeed, usually, rises several feet above the porous bed or vein in which it is found. The shallow wells, however, of which there are many only 10 to 15 or 20 feet deep, generally are supplied by the seepage of surface water.

WELLS ON THE AREA OF LAKE AGASSIZ IN MINNESOTA

TRAVERSE COUNTY.

Browns Valley.—The section of the artesian well in this village has been given on page 89, and an analysis of its water on page 539.

Doleysmount.—Rudolph Heidelberger, southeast quarter of section 6: Well, 36 feet deep; till, 22 feet; and sand with water, not rising, 14 feet, to the bottom and continuing lower.

Emil Heidelberger, northeast quarter of section 6: Artesian well, 79 feet deep, in drift, chiefly till; flow scanty.

Croke.—Cyrus B. Stevens, northeast quarter of section 12: Well, 60 feet deep; soil, gravel, and sand, 5 feet; till, 50 feet; and quicksand, penetrated 5 feet and continuing lower, so soft that the auger fell 3 or 4 feet. Water, so alkaline that it can not be used, rose from this sand to 3 feet below the surface.

Clifton.—William McClymond, in section 13, has two artesian wells, each about 85 feet deep, in drift. There are several other flowing wells, 60 to 75 feet deep, in this northeastern part of the township.

J. T. Blaisdell, in section 31, has two flowing wells. The one at the farmhouse is 119 feet deep, bored all the way in till, yellowish for 25 or 30 feet, and dark bluish below, hardest in its lowest 6 or 8 feet, beneath which water was struck in coarse gravel, and rises to the surface, overflowing; a good supply. The other well, nearly a mile northeast from the foregoing, is 182 feet deep. Water rises from quicksand at the bottom, and is of good quality, but only a small supply. This well was bored after that at the farmhouse, so that water was expected at 119 feet, but none was found, nor was any layer of gravel and sand noticed at that depth.

Wheaton.—Common wells at Wheaton are 25 to 35 feet deep, in till; water usually rises to 10 or 15 feet below the surface, and is mostly alkaline; but the town well, in the middle of the street, 30 feet deep, drained every day by its general use, has fairly good water.

Boring for an artesian town well went to the depth of 300 feet, obtaining no flow at the surface. This well found at 200 feet a large supply of good water, which rose to 15 feet below the surface. It came from the top of a bed of sand and gravel about 10 feet thick, and rose with such force that it filled 40 feet of the pipe with sand. Next below was clay, probably till, about 65 feet, lying on Cretaceous shale, into which the boring was continued about 25 feet.

Another unsuccessful boring for artesian water was done in this village at T. E. Dunn's livery stable, to a depth of 390 feet. Till extended from the surface to a depth of 280 feet, inclosing layers of sand and gravel at 130 feet and at other depths to 200 feet. The lower 110 feet were hard, dark bluish shale, probably belonging to the Fort Benton division of the Cretaceous series.

Tintah.—Several shallow wells in this township have ample flows of good water from the drift. The well at the railway tank is 48 feet deep, with water rising only to the surface. J. E. Henry has three or more artesian wells at his extensive farm buildings near Tintah railway station. The well at the farmhouse is 45 feet deep, with water rising nearly to the surface, but not overflowing. At the barns, about 50 rods southeast, a well 67 feet deep flows 6 inches above the surface. Another well, about halfway between these two, is 45 feet deep, with water rising 6 feet above the surface.

Taylor.—In the north edge of this township, and near the Bois des Sioux River, Mr. Bruce has an artesian well 106 feet deep, flowing 3 gallons per minute.

C. M. Harmon, northwest quarter of section 3: Well, 73 feet deep; till extends to the depth of 70 feet, being yellowish for its first 15 feet, and dark bluish below, yielding much alkaline water at 18 feet, also some seeping water from lower gravelly streaks. At the bottom, water of excellent quality was found in a bed of gravel and sand, and rose within a few minutes to a level 6 feet below the surface. This water-bearing bed is only 3 or 4 feet thick, as was shown by boring deeper, when the pipe shut off the water, and was therefore lifted back.

David Warriner, section 31: A boring at the farmhouse went 165 feet in till, finding no supply of water. About 15 rods distant to the north, on land 6 feet lower, another well went 50 feet in till, to gravel and sand yielding a large supply of good water, which quickly rose to a permanent level 14 feet below the surface.

A large number of other wells in this county are described in Geology of Minnesota, Vol. II, pp. 530, 531.

WILKIN COUNTY.

Champion.—This township has probably as many as thirty artesian wells, ranging from 50 to 110 feet in depth, in the drift. One of the earliest bored and most copious in flow is on the Fountain Valley Farm, section 3, owned by Col. C. H. Brush & Co. This well is 66 feet deep, being till, 56 feet, and sand, 10 feet, and continuing deeper, from which the artesian flow is obtained. The diameter of the pipe is 1 foot, reduced below to 7 inches. A large stream of very clear, cold water constantly flows from this well, its estimated volume being 7 or 8 barrels per minute, or about 250 gallons. The water is of excellent quality for house and farm use, but is hard and slightly irony, and deposits a rusty sediment in the channel of the stream. Its temperature is 46° F.

In section 11, nearly 2 miles southeast from the foregoing, a well was bored to the depth of about 50 feet, and was left dry by the workmen when they stopped at night; but in the morning it was found overflowing and flooding the surrounding land. In 1887 this well had been thus running six years, baffling all efforts to shut it off, and spoiling or damaging a tract equal to half a section by its inundation.

George Barnes, northwest quarter of section 14: Artesian well, 83 feet deep, in till, to quicksand at the bottom, into which the auger fell suddenly 2 or 3 feet, obtaining a very powerful flow of water.

George W. Mace, southeast quarter of section 22: Well, 107 feet deep; water rises 5 feet above the surface, but has only a feeble flow.

T. B. Bushnell, southwest quarter of section 23, about 40 rods east of the last and on land several feet higher: Well, 105 feet; artesian water rises with much force, probably sufficient to carry it to a height of 40 feet. It flows 22 gallons per minute from a pipe 1 inch in diameter.

Nash Brothers, northwest quarter of section 26, about a half mile south of the last: Well also 105 feet; water, found at 95 feet, rises with similar force, bringing up quicksand. It has a temperature of 48° F., and is of the best quality, being softer than the water of neighboring shallow wells.

In the southeast quarter of section 34, near Tintah, a well 95 feet deep found much lignite in the upper part of a water-bearing bed of sand, into which the boring went 5 feet, obtaining water that rises nearly to the surface.

Campbell.—The railroad well in the village, 260 feet deep, went all the way in till, excepting occasional layers of sand and gravel, mostly thin, but at one place 8 feet thick, from 165 to 173 feet below the top. Numerous fragments of lignite were found in the till of this well, especially from 125 to 150 feet, and they were abundantly mixed with the thick bed of sand mentioned, making about 10 per cent of the deposit. Some of its pieces brought up from the depth of 173 feet were incrusted with pyrite. The lower portion of the pipe becoming filled with mud, it was found necessary to puncture the pipe and admit water above the clay filling. This was done at 176 feet. The water rose within 4 feet of the surface. Higher water-bearing veins were encountered in boring the well at 125, 150, and 165 feet.

F. W. Maechler, of Campbell, who has bored nearly a hundred deep wells within a radius of 5 miles, states that shallow wells, which are dug 10 to 25 feet deep, have, almost without exception, disagreeable alkaline water; but that the bored wells, 50 to 100 feet, or occasionally more, in depth, have very good water, frequently artesian. At Mr. Maechler's house the well is 55 feet deep; till, 20 feet; sand, with some layers of fine gravel, 35 feet, and continuing lower; water rises to 3 feet below the surface. This exceptionally thick bed of sand also supplies water to several other wells in the village; but some of the wells here, including the railroad well before noted, are wholly till, inclosing no important sand or gravel layer and having no inflow of water, for a depth of 100 to 125 feet.

W. D. Cross, 1 mile northwest from Campbell village: Boring, 176 feet, entirely in till, less stony in its lower half and there containing streaks of gravel and sand 6 to 12 inches thick; no supply of water. Another well, however, 124 feet deep, bored only a few hundred feet distant, was quite different, being till, 81 feet; sand and

gravel, 31 feet, and sandy clay, 12 feet, continuing lower. This well obtains artesian water, just flowing to the surface; but it is found to be inexhaustible, and can be lowered only a few feet by pumping.

In section 22 a boring for Charles Mullen went 272 feet, obtaining no water. A mile to the southwest, at Mr. Maechler's farmhouse, in the northwest quarter of section 27, a well 88 feet deep has water which rises to 18 inches below the surface and can not be lowered by pumping.

Bradford.—Charles Covell, southeast quarter of section 10: Artesian well, 50 feet deep; water rises 15 feet above the surface.

W. H. Fish, southeast quarter of section 12, on land 20 feet above the foregoing: Well, 49 feet, wholly in till; water, slightly alkaline, rose from gravel and sand at the bottom to a permanent level 3 feet below the surface. This well was dug with a diameter of 5 feet, and was thus filled almost to overflowing within ten minutes after the water was reached.

Henry Poor, northeast quarter of section 14: Artesian well, 48 feet deep, bored 2 inches in diameter; very copious flow, not under control, rising in a bowl-like spring about 6 feet across, and running away in shallow depressions of the adjoining prairie.

Edward H. Boustead, southwest quarter of section 18: Artesian well, 85 feet deep; water of good quality, pleasant in taste, and found to be healthful, but peculiar in containing gas. Immediately after the water reaches the surface the gas collects into very minute bubbles, so that the water for about a minute seems to be filled with light gray dust particles, after which it quickly becomes clear, as it also was on first flowing from the pipe.

C. W. Keyes, in the southwest quarter of section 31, about a mile northeast of Campbell, has a flowing well of good water, 64 feet deep. Previous to this boring, a well dug 61 feet in till, supplied mainly with surface water of inferior quality from a thin bed of gravel and sand at 21 feet, had been used several years.

Breckenridge.—Borings for artesian wells in this town have been unsuccessful. The drift-sheet, chiefly till, inclosing only few and thin layers of sand and gravel, is found to have a thickness of 202 feet, underlain by dark Cretaceous shale, probably the Fort Benton formation. The shallow wells are mostly alkaline, and the water of the Red River, which is better, has been generally used.

Andrea.—The drift in this township is commonly till to the depth of 40 or 50 feet or more, its lowest 4 or 5 feet being very hard; then quicksand, 5 to 10 feet or more, into which the boring must go a few feet, as in the following examples of artesian wells, to get a good supply of water.

L. Manske, northeast quarter of section 10: Flowing well, 50 feet deep.

P. H. Funkley, southeast quarter of section 26: Well, 60 feet; large flow; rising 10 feet above the surface.

R. McIntosh, southeast quarter of section 27: Flowing well, 86 feet deep.

P. Heider; northwest quarter of section 34: Well, 43 feet; water rises 4 feet above the surface.

Akron.—Albert Lutti, northeast quarter of section 34: Artesian well, 36 feet deep; in till, to gravel and sand at the bottom; water of good quality rises 4 feet above the surface. Another flowing well in the southeast quarter of this section is only 34 feet deep.

McCauleyville.—The two following wells are in the village, about 25 feet above the low-water stage of the Red River, whose alluvium is thus known to reach some 20 feet below that level.

James Nolan: Well, 33½ feet deep; soil, 2½ feet; brownish yellow alluvial clay, 26 feet; dark quicksand, 4 feet; gravel containing shells, like the bottom of a lake, with water, 1 foot and continuing lower.

In Cyril Boutiette's well, alluvial clay extended to the depth of 45 feet, where was found a layer of abundant remains of rushes and sedges, some of them having their flowering and fruiting panicles and spikes distinctly preserved.

Mitchell.—C. R. Gleason, northeast quarter of section 28: Well, 27 feet; soil, 2; yellowish gray till, 6; gray sand, ½ inch; much harder dark bluish till, 18 feet, containing plentiful rock fragments up to 6 inches in diameter; underlain by sandy black mud, in which were many small gasteropod shells. This doubtless interglacial fossiliferous layer, and an interglacial forest bed found under 12 feet of till at Barnesville, in Clay County, both within the area that was covered by Lake Agassiz, show that there was a sufficiently long warm epoch in the midst of the great Ice age to cause the ice-sheet to retreat northward beyond Barnesville.

The recession of the ice seems referable, as indicated on page 280, to the Aftonian stage of the Glacial period, between the Kansan and Iowan stages of ice accumulation. The upper part of the great channel occupied by Lakes Traverse and Big Stone and the Minnesota River was probably eroded by southward outflow from the Red River Valley at that time to a depth somewhat below the level of the upper or Herman beach of Lake Agassiz, and was not subsequently filled with drift when the ice-sheet again covered the land far southward to its Iowan limits. This interglacial erosion may have reached below the levels of the fossiliferous layers in the wells of Mitchell and Barnesville, allowing these parts of the Red River Valley to have a land surface, while its deeper central part held a lake; or, more probably, as I think, the valley may then have sloped southward, on account of differential northward elevation of the region, so that no lake would be formed during the Aftonian glacial recession in this basin.[1]

Atherton.—In the southwest quarter of section 9, a well 37 feet deep has water which rises 3 feet above the surface.

[1] Am. Geologist, Vol. XV, pp. 279–282, May, 1895.

Michael Starrs, southeast quarter of section 20: Well, 45 feet deep, in till, to gravel at the bottom, from which water rises to 4 feet below the surface, and flows away by a ditch to the Deerhorn Creek, only about 50 feet distant.

Charles Funkhandel, in the northeast quarter of section 35, has a well only 11 feet deep, which yields a copious artesian flow.

Descriptions of many other wells in this county are given in Geology of Minnesota, Vol. II, pages 527–530.

CLAY COUNTY.

Barnesville.—This city has no artesian wells, and the common wells are 12 to 40 feet deep, mostly in till which incloses beds of gravel and sand. A boring by John Marth to the depth of 150 feet, on the west side of the main street, found no artesian water.

Mr. Marth has a shallow well, 13 feet deep, which is remarkable for its interglacial forest bed. The section was soil (the blackened surface of the till), 2 feet; yellowish till, 10 feet; then quicksand, 1 foot, containing several branches and trunks of trees, thought to be tamarack, up to 8 inches in diameter, lying across the well, which, together with the inflow of water, prevented further digging.

Rudolph Sieber, in the southwest quarter of section 12, Barnesville Township, close north of a small creek, has an artesian well 35 feet deep, from which water rises with a strong flow to a height of 16 feet or more above the surface.

Sabin.—Angus Murray: Well, about 80 feet in till, to gravel, from which water of excellent quality rose to a level only 3 or 4 feet below the surface. The Minneapolis and Northern Elevator Company has a similar water supply in a well 90 feet deep. Other wells about 20 feet deep in this village, dug mostly in beach sand, have good water.

A. E. Henderson, on the Pleasant Ridge Farm, 1 mile north of Sabin, has a well 72 feet deep, with water rising almost to the surface.

Glyndon.—In the southern part of this township, 3 to 5 miles northeast of Sabin, there are several artesian wells 50 to 75 feet deep.

Two borings at the elevator of G. S. Barnes & Co., in Glyndon Village, failed to obtain water, and the augers were broken in the till, called "hardpan," at the bottom. In the deeper one of these borings a depth of 125 feet was reached, the section being reported as soil, 3 feet; quicksand, 22 feet; dark clay, free from stones, 75 feet; very hard yellowish till, 15 feet; and softer till, 10 feet. The till in these borings is said to have been so hard that only a tenth as fast progress could be made in it as in the dark alluvial clay above. A log of wood, which was called "cedar," about a foot in diameter, was encountered by one of these borings in the dark alluvium, 35 feet below the surface; and the other boring, about 12 feet distant, found "rotten chips" of wood

at the same depth. In the well at the railroad engine house, somewhat farther west, vegetable deposits, including sheets of turf and drift wood, were found at the depth of 13 to 18 feet.

Moorhead.—An unsuccessful boring done in 1889 by this city, in the hope of obtaining artesian water or gas, went to the depth of 1,750 feet. From comparison and combination of notes published by Prof. N. H. Winchell,[1] with others supplied by Mr. John T. Gray and Prof. C. W. Hall, the section appears to have been as follows: Alluvial and lacustrine deposits, chiefly fine clayey silt, 55 feet; pebbly clay, apparently till, 55 feet; gravel and sand, 35 feet, yielding water which rose nearly to the surface; till, with occasional layers of sand, 75 feet, extending to the base of the drift at 220 feet; bluish and greenish shales, with beds of sand, 145 feet, probably belonging to the Fort Benton formation, of Cretaceous age; and granitoid and gneissic rocks, doubtless of Archean age, beginning at 365 feet, of which a thickness of 1,385 feet was penetrated.

Artesian wells in the drift have been obtained here as follows:

At J. G. Burgquist's brickyard a well 165 feet deep flows 8 inches above the surface.

Minneapolis and Northern Elevator Company: Well, 200 feet deep, with water rising 5 feet above the surface. In another well, 200 feet deep, at Lamb Bros.' brickyard, the water rises only to a level 6 feet below the surface.

These deep wells have water of good quality, excepting its hardness, while the water of shallow wells, 10 to 25 feet deep, coming from a bed of sand 3 to 10 feet thick, inclosed above and below by the alluvial clay, is somewhat alkaline. Most of the water used for domestic purposes in both Moorhead and Fargo is taken from the Red River by waterworks.

At the Artesian stock farm of W. R. Tanner & Co., section 24, Moorhead, a well 228 feet deep found water in a bed of sand forming the lowest 3 feet of the section, and rises 2½ feet above the surface. It is free from any saline and alkaline taste, and can be used for washing with soap. Two previous borings here were stopped at the depth of about 180 feet by encountering bowlders in the till. Most of the deep wells within a few miles about this farm get water in layers of gravel and sand inclosed in the till at depths from 160 to 200 feet, from which the water rises to a few feet below the surface, not overflowing.

Kragnes.—Minneapolis and Northern Elevator Company: Artesian well, 155 feet deep; water rises 4 feet above the surface, there flowing only 30 barrels in twenty-four hours from a 2-inch pipe; but this well, when pumped, supplies an abundance of water, and can not be reduced more than 20 feet below the surface.

Common wells on farms around Kragnes are 15 to 30 feet deep.

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[1] Geol. and Nat. Hist. Survey of Minnesota, Bulletin No. 5, "Natural gas in Minnesota," 1889, pp. 27–31.

Georgetown.—C. B. Hill, Osborne Farm, southeast quarter of section 33: Artesian well, 180 feet deep; the water, rising 4 feet above the surface, is of good quality, but not so suitable for use in the boilers of steam engines as the river water.

Several flowing wells in the northern part of this township range from 165 to 180 feet in depth.

Numerous other records of wells in Clay County are noted in Geology of Minnesota, Vol. II, pages 667–669.

NORMAN COUNTY.

Perley.— The Minneapolis and Northern Elevator Company has an artesian well about 200 feet deep. Another of similar depth is at A. T. Aabye's house.

Lake Ida.—Ferdinand Burkhardt, southwest quarter of section 2: Well, 80 feet deep; yellow till, 10 feet; blue till, 70 feet; water seeps, filling the well to about 25 feet below the surface.

Ada.—The town well, 217 feet deep, 4 inches in diameter, supplies a stream which partly fills a 1-inch pipe. It was bored in 1881, and has since been running at the rate of about 100 barrels per day. This water is very clear, and forms no irony sediment. Its cool temperature (47° F.) and its excellent quality for drinking and domestic uses, being called soft water, nearly equal to rain water for washing, make this a very satisfactory investment for the town. Its cost was about $500.

Common wells of Ada and its vicinity are 10 to 20 feet deep. Their water is hard, but is considered healthful for drinking.

Henry Downs, one-fourth of a mile west of Ada, has a flowing well about 90 feet deep.

McDonaldsville.—S. A. Farnsworth, southeast quarter of section 4: Well, 75 feet; soil, 3 feet; yellow alluvial clay, 10 feet; blue clay, alluvial in its upper part, but doubtless including a considerable depth of till below, 56 feet; a harder portion of the till, called "hardpan," 5 feet; gravel, 1 foot, and extending lower; artesian water, of similar quality and amount of flow as the Ada town well.

Pleasant View.—Two artesian wells, similar in their sections to the last, but more feeble in flow, were noted in this township, namely, one, 65 feet deep, on William Hein's farm, in the southwest quarter of section 2, and the other, 76 feet deep, at F. S. Flower's, in the southeast quarter of section 22.

Anthony.—Ole B. Halvorson, section 19: Well, 12 feet; soil, 2 feet; yellow till, 10 feet; water comes from a layer of sand 6 inches thick at the bottom, rising 6 feet to its permanent level in a half day. Mr. Halvorson has also bored down 65 feet, finding the section wholly till, dark bluish below the first 12 feet; no layers of sand and no additional supply of water. Common wells in this vicinity range from 12 or 15 feet to 30 feet in depth. The water is slightly alkaline, but is quite tolerable and apparently healthful when the supply is daily renewed by pumping.

Halstad.—The Minneapolis and Northern Elevator Company has an artesian well, which is reported to be about 250 feet deep. The common wells are similar to those of Anthony in their depths and quality of water.

Lockhart.—This township and others adjoining it have many flowing wells, varying from 100 to 200 feet in depth.

On William Fisher's farm, in section 5, three artesian wells are each about 130 feet deep. Their water, which rises 4 feet above the surface, is free from any alkaline or saline taste.

Leo Gnadt, section 6: Artesian well, 165 feet deep, from which good water rises 3 feet above the surface.

At the buildings of the Lockhart Farm, in section 29, a well 5 inches in diameter was bored to the depth of 142 feet in the autumn of 1880, the section being as follows: Soil, 2 feet; yellow alluvial clay, or perhaps in part till, about 10 feet; blue till, 130 feet, to sand at the bottom, from which water of excellent quality rose to the surface with a powerful flow. The water was allowed to run in its full amount during a month or more, flooding a considerable tract for a mile northward. With the water much sand was brought up and deposited by the stream in a neighboring slough, its estimated volume being approximately 300 cubic yards, spread on the average a foot thick over a space about 100 feet in diameter. The flow of this well was reduced after a time by a cap and gauge to a small stream; but in the following December it ceased, because the bottom of the pipe for about 20 feet had been compactly filled with sand.

In July, 1881, a second well of similar diameter was bored a short distance south of the preceding. Till extended to a depth of 141 feet, below which the boring went into a bed of sand 16 feet, from which water rose to 15 feet above the surface, flowing through an inch pipe about 60 barrels per day. Many fragments of lignite, up to 3 inches long, were found in several layers in the sand bed, probably a half bushel of it in all being brought up as the boring progressed, but no lignite was encountered in the till. One piece of wood 3 or 4 inches long, with numerous smaller fragments of wood, was also found in the sand.

Several other artesian wells similar to these have since been bored on this farm. One of these, about 700 feet distant from the first well, struck water at 137 feet, which rose with a much stronger and alarming flow, and soon found vent also alongside the pipe, making a large hole and inundating the vicinity of the farm buildings and much adjoining land. To carry away this water many laborers were quickly set to digging ditches along a distance of several miles to the west. After some two weeks, however, the heavy flow mostly ceased, becoming principally confined to the pipe, with only a moderate and controllable quantity coming to the surface outside the pipe.

Shely.—Iver Nilson, in section 14, has a well 219 feet deep, with water at first rising to the surface, but afterward to about 4 feet below the surface. This well goes wholly through drift, nearly all till, but including occasional thin beds of gravel

and sand. The last 5 or 6 feet were quicksand, extending also deeper, from which the water came. One and a half miles south of this a well 225 feet deep has water rising to 3 or 4 feet below the surface; and a half mile farther south a well with similar water supply is 209 feet deep. Most of the flowing or very deep wells in this township and northward are slightly saline, but Mr. Nilson's has no such taste, and is well adapted for washing with soap, being said to be "as soft as rain water."

The common wells of this region (a belt of morainic till crossing the Red River Valley from east to west) are 10 to 25 feet deep, obtaining water which seeps from the upper part of the till. The water, though hard and slightly alkaline, is not generally unhealthful for farm and house use, excepting in wells that are contaminated by the decay of wooden curbing. When these wells are allowed to remain stagnant, without being frequently drawn from in large amount, the water becomes very offensive in odor and taste.

POLK COUNTY.

Liberty.—Jacob Stambaugh, northeast quarter of section 33: Well, 52 feet; soil, 2 feet; gravel and sand of the McCauleyville beach, 16 feet; bluish-gray till, very hard, 34 feet, to quicksand, from which water, of good quality but hard, rose 24 feet in ten minutes, to its permanent level. Several pieces of wood were found in the till of this well. Another well here, only 17 feet deep, finds an ample supply of water at the base of the beach gravel and sand.

Reis.—At Beltrami station the Red River Valley Elevator Company has an artesian well 140 feet deep, from which water rises 12 feet above the surface. It has no saline nor alkaline taste, and is less hard than the water of the neighboring shallow wells.

George C. Reis, northeast quarter of section 32: Artesian well, 147 feet deep; soil, 2 feet; yellow till, partly so hard as to need to be dug with a pick, 8 feet; and dark-bluish till, also very hard, 137 feet, containing occasional layers of sand and gravel up to 6 inches in thickness. Water, of the same excellent quality as at Beltrami, rises 12 feet above the surface. This well is 5 inches in diameter, reduced at the top to a 1-inch pipe, from which the flow amounts to about 3 gallons per minute, or 150 barrels in twenty-four hours.

Russia.—Eric Bjerk, northeast quarter of section 2: Well, 60 feet deep; soil, 2 feet; till, dark bluish, excepting near the surface, so soft that it could be all spaded, 58 feet, to dark sand which extends at least 2 feet. At this depth the well was left dry by the workmen at the end of their day's labor, but in the morning it was filled with water and overflowing.

L. T. Soule, the Russia Farm, section 19: Well, 124 feet; soil, 2 feet; yellow alluvial clay, 3 feet; quicksand, 1 foot; dark bluish till, 104 feet, with no layers of sand or gravel; sand, fine above and growing coarser downward, 13 feet; and gravel,

1 foot and continuing below. All the sand bed yields a feeble artesian flow, and a strong flow comes from the gravel. It is hard water, but excellent for drinking, having no alkaline taste.

Hammond.—W. S. Rattray, northeast quarter of section 15: Well, 12 feet; soil, 2 feet; yellow alluvial clay, 7 feet; sand, 3 feet, underlain by dark blue clay. Good water, becoming 3 feet deep, issues from the lowest foot of the sand. Other wells in this township are 10 to 15 feet deep, many of them having objectionably alkaline water.

Fairfax.—In the west part of section 28 a well 80 feet deep has water which rises 8 feet above the surface. There are also several other flowing wells within 2 or 3 miles eastward and southward, ranging from 80 to 112 feet in depth.

Nine flowing wells in the northeast quarter of section 18 range from 185 to 205 feet in depth; and one in the southwest quarter of this section is 173 feet deep.

Andover.—E. S. Corser, Southside Farm, section 3: A boring 205 feet deep in drift, mostly till, obtained no artesian water.

In the northeast quarter of section 23 an unsuccessful boring to the depth of 111 feet went through black soil 1½ feet, alluvial clay 18 feet; a vegetal deposit of leaves and partially decayed wood 3 feet; and then clay, probably mostly till, to the bottom.

Carman.—The artesian well at E. S. Corser's elevator, in this village, is 191 feet deep, being yellowish alluvial clay, 11 feet; yellowish quicksand, 3 feet, in which shallow wells get an ample supply of water, slightly alkaline; and dark bluish clay, alluvial at the top, but soon changing to till, 177 feet, containing occasional thin layers of sand below the depth of 160 feet from the surface. A bed of fine gravel and sand was reached at the bottom, from which water rose to the height of 10 feet above the surface, and flows at the rate of 100 barrels a day. The water, of which an analysis is given on page 540, is very good for drinking and for all farm and domestic uses. For washing with soap and for use in engine boilers, it is much better than the water of the river. The cost of the well, bored 5 inches in diameter, was $600.

Crookston.—Nels Swanson, in the south edge of the city, south of the Red Lake River: Artesian well, 185 feet deep in till; alluvial clay above and till below for the greater part of its depth, with occasional thin veins of sand and gravel; water of good quality.

Another flowing well, owned by B. Sampson, about 20 rods north of the preceding, is also 185 feet deep, its lowest 6 feet being sand.

S. M. McKee, southwest quarter of section 3: Well, 230 feet, with water rising from the bottom to 12 feet below the surface.

H. A. Wyand, southwest quarter of section 5: Well, 236 feet; till, 155 feet; a harder deposit of till, called "hardpan," 14 feet; fine gravel and sand, 23 feet, with water rising from its top to 8 feet below the surface; again till, in part moister and softer than the higher till, 38 feet; and quicksand, 6 feet, also continuing lower, from which water rises to 1½ feet below the surface.

Harvey Cook, southwest quarter of section 8: Artesian well, about 180 feet deep; water rises 1½ feet above the surface.

There are many artesian wells, probably not less than a hundred, within a radius of 10 miles around Crookston, ranging from 165 to 285 feet in depth, wholly in the drift. Most of them have excellent water, free from any saline or alkaline taste.

Fisher.—Red Lake Mills, in the village: Well, 190 feet deep; soil, 2 feet; yellowish alluvial clay, 12 feet; quicksand, about 1 foot, yielding water of sufficient amount and good quality for common wells; dark bluish clay, mostly till, through all the remaining depth below, except that it incloses infrequent layers of sand 6 to 12 inches thick, from one of which, at the depth of about 125 feet, water rose to 6 feet below the surface, but no artesian flow was found.

L. Freeman, in the north edge of the village: Well, 198 feet; alluvial clay, 40 feet; and till, inclosing occasional seams of sand and gravel up to 1 foot in thickness, extended thence to the bottom. Water of good quality rises to 9 feet below the surface. By tapping the pipe at a slightly lower level it flows to the milk house and barnyard, which are situated near the well, on the slope descending to the river.

Hugh Thompson and F. S. De Mers, in the south part of the village: Artesian well, 285 feet deep, mainly till, but beds of gravel and sand containing fresh water were encountered at 133 feet and 190 feet, each of these beds being about 10 feet thick. Brackish water from sand at the bottom rises to 1 foot below the surface. Though perceptibly saline, it is relished by horses and cattle and is found to agree with them.

It seems very significant that this well, the first noted with considerable salt water in proceeding northward on the Minnesota side of the Red River, is close to a boring by C. W. Webster in the southwest quarter of section 14, about a mile east of Fisher, which at a depth of 300 feet reached a very fine-grained white sandstone, doubtless the Dakota sandstone, as that formation is encountered at a similar depth by numerous wells on the opposite side of this valley plain in North Dakota. This sandstone, as stated in the earlier part of this chapter, is probably the source of the saline water commonly obtained by deep wells in the drift northward from the vicinity of Crookston and Fisher to southern Manitoba.

St. Hilaire.—An artesian well 146 feet deep, wholly in the drift, chiefly till, was bored about three-fourths of a mile south of the depot, near where the Crookston road and railway turn southwestward; good water, but scanty flow.

Euclid.—Two miles northeast of Euclid, Mr. Allen has a flowing well about 75 feet deep; water rising only a little above the surface.

In the village common wells obtain an inexhaustible supply of good water at the depth of 12 to 18 feet, the section being soil, 2 feet; yellow till, spaded, 6 to 10 feet; and gray till, darker and much harder, requiring to be picked, several feet, to a bed of quicksand from which the water rises to a permanent level 6 to 8 feet below the surface.

Keystone.—The first artesian well at the buildings of the Keystone Farm, in section 23, was bored in 1881, having a depth of 110 feet. The section was soil, 2 feet; yellow alluvial clay, 12 feet; sand, yielding considerable water, about 2 inches; dark bluish till, 71 feet; and sand and gravel, 25 feet. Water of excellent quality, without salty taste and so soft that it can be used for washing with soap, flows at the rate of 40 barrels per day, or nearly a gallon per minute, the diameter of the well pipe being 5 inches. During all the boring below 85 feet water rose to the surface, but only in very small quantity, until a hard layer of gravel was reached at the bottom. Seven other artesian wells, all obtaining good water in the drift, have since been bored here, ranging in depth from 95 to 150 feet.

Another well on this farm, sunk to the depth of 250 feet, reached the Dakota sandstone, the very fine white sand coming up with the water and giving it a milky appearance. It yielded a copious artesian flow of brackish water, and was therefore abandoned.

Angus.—Several borings 200 to 300 feet deep in Angus village and its vicinity have found no artesian water.

A. D. Andrews, southwest quarter of section 10: Well, 82 feet; soil, 2 feet; alluvial sandy silt, 5 feet; hard, dark bluish till, mostly picked, 43 feet; much harder till, with more frequent bowlders, 28 feet; soft sand and gravel, 4 feet and continuing lower, from which good but hard water rose immediately to its permanent level, 20 feet below the surface.

A. O. Bailey, section 27: Well, 253 feet; soil, 2 feet; mainly till below, with no important beds or veins of sand and gravel before reaching the bottom, whence an ample supply of good water, like that of the less deep artesian wells on the Keystone Farm, rose to 10 feet below the surface.

Tabor.—The depths of two flowing wells in the southeast part of this township are reported to be about 45 and 70 feet. Common wells are mostly 10 to 15 feet deep, with copious supply of healthful water from sandy layers in the alluvial clay.

Farley.—Furlong & Ramsey; southeast quarter of section 27: Two borings to depths of about 165 feet and 200 feet obtained salt water, which rose nearly to the surface, but is not used. This large farm takes its water supply from two shallow wells, each 12 feet deep, and from surface pools dug a few feet deep.

MARSHALL COUNTY.

Warren.—At the elevator of the Warren Manufacturing Company a well 130 feet deep has slightly saline water, which rises from the bottom to 5 feet below the surface. Its section was alluvial clay, 50 feet, or quite probably the lower part of this is till; then a bed of gravel, 10 feet, with much water, which does not rise to the surface; dark bluish till, 50 feet; and sand and gravel, 20 feet and continuing lower.

The boring for a town well showed a great thickness of till beneath this section, extending to the depth of 260 feet.

L. Loughridge, in the village: Well, 96 feet; water rises to 4 feet below the surface, and is capable of supplying about 25 barrels daily.

Pembina Farming Company, 1 mile southeast of Warren: Well, 180 feet, obtaining excellent water, not saline, which rises to 20 feet below the surface.

March & Spalding, 1 mile west of the village: Well, 143 feet; water rises to 4 feet below the surface, supplying 75 barrels in twenty-four hours.

The common wells of this vicinity are 10 to 30 feet deep, obtaining usually an abundant supply of water, which is very hard, but has little or no alkaline taste.

Argyle.—A boring for a town well in this village, 150 feet deep in drift, chiefly till, was stopped at this depth by a bowlder, having found no considerable supply of water. Gas which could be ignited issued from the depth of 70 to 100 feet.

Minneapolis and Northern Elevator Company: Flowing well, 155 feet deep, with water rising only slightly above the surface, but yielding a large supply when pumped. It is saline, but is used for the engine boiler.

Middle River.—William Carrese, section 22, 1 mile south of Argyle: Flowing well, 285 feet deep; brackish water rises 2 feet above the surface.

O. D. Ford, Stone Farm, section 33: Flowing well, 218 feet deep; water, found at 185 feet, rises 2 feet above the surface; brackish, but good for cattle.

Bloomer.—On the Argyle Farm, section 23, a boring 200 feet or more in depth obtained no artesian water.

Wanger.—In the northeast quarter of section 10 a boring found combustible gas at 80 feet.

James Headrick, southeast quarter of section 28: Well, 28 feet deep, dug 26 feet, there finding a cavity 2 feet deep, full of running water, which passes through the well with a southwestward current estimated at 2 miles per hour. A bucket dipping water is apt to be swept away under the southwest side of the well. The water runs over a bed of fine gravel and forms sand bars in the bottom of the well, which therefore needs to be frequently cleared out. The section was soil, 2 feet; clay, 4 feet; sand and gravel, 2 feet; and till, 18 feet. Along the course of the Tamarack River for 8 miles thence westward to Stephen it receives many small springs, issuing nearly on a level with the river; and some of these are probably formed by the stream that flows through this well.

Tamarack.—C. W. Culbertson, section 31: Flowing well, 74 feet deep; water rises 10 feet above the surface; saline, but good for stock.

Stephen.—Town well, about 240 feet deep; water rises 3 or 4 feet above the surface, but it is not a large supply, even when pumped from at 10 feet below the surface; too saline for any use.

On the Stephen Farm, owned by Charles M. Ramsey, another saline artesian well, unused, is 220 feet deep.

Parker.—J. Q. Cronkhite, section 25: Flowing well, 95 feet deep, quite salty water, rising about 10 feet above the surface.

Augsburg.—Wheeler & Culbertson, section 32: Boring about 300 feet deep; no supply of water.

Sinnott.—John Hughes, northeast quarter of section 28: Well, 42 feet; soil, 2 feet; soft, stratified alluvial clay, yellowish above, but dark bluish for the greater part of its thickness, 38 feet; very hard, yellowish gray till, dug into only 2 feet, containing sandy veins or layers, from which water seeping into the well filled it 7 feet in a half day. Within two weeks in the dry season, when it was dug, the water rose to a depth of 30 feet. It is of good quality, hard, but with no saline taste.

KITTSON COUNTY.

Donaldson.—E. N. Davis, in the northwest quarter of section 29, Davis, close east of Donaldson station, has a flowing well 45 feet deep, which was bored in 1880 in a quarter of a day with an ordinary 2-inch auger. Its flow ever since that time has been nearly constant, at the rate of about 8 gallons a minute, or more than 300 barrels daily. The section was soil, 1½ feet; yellowish gray alluvial clay, 10 feet; dark bluish alluvial clay, 28 feet; hard dark gray till, 5 feet; and a very hard ferruginous layer, one-half foot, from beneath which the water rose quickly to the surface, bringing up sand and gravel. The temperature of the water is 42° F. Though salty to the taste, farm stock thrive with this as their only supply of water, which they drink very freely; and it has been used by people, with no apparent injury, as the only water for drinking and cooking through several weeks of drought. The height to which it will rise is known to be more than 23 feet, at which height the flow seemed to be undiminished. On stopping the pipe of this well the water issued as a spring several rods distant.

Kennedy.—A boring by the Kennedy Land and Town Company went to the depth of 225 feet, obtaining no artesian water. Below the alluvial clay of the surface the section was chiefly till. Bowlders were observed at the depth of 45 feet, and bowlders and gravel in the till were encountered thence to the bottom. Water from layers or veins of sand and gravel rose nearly to the surface, but was too saline to be used.

Skane.—The Fort Donaldson Farm, in section 20, has an artesian well 95 feet deep, with water likewise so salty that it can not be used. But some other deep wells in this township obtain fresh water of good quality, as Lars Lundgren's well, in the southeast quarter of section 7, which is 119 feet deep, with water rising just to the surface, not overflowing.

Hallock.—Eklund elevator: Well, 125 feet deep; alluvial clay above, succeeded by till below for nearly all the depth; very saline water rises from gravel and sand at the bottom to a permanent level 4 or 5 feet below the surface.

L. N. Eklund, a sixth of a mile east of the depot and elevator: Well, 90 feet deep; also very salty water, rising to 5 feet below the surface. Another well, only 2 rods distant, obtained saline water at 80 feet, which rose immediately just to the surface, not overflowing.

L. B. Riddell, close west of Hallock village: Well, 71 feet deep; saline water, not used, rises to 4 feet below the surface.

Granville.—W. J. Ross, in section 7, has a flowing well of fresh water, only 30 feet deep. John Jenkins, jr., in section 18, a mile south of the last, also has a flowing well of similar depth and good quality of water.

Northcote.—Peter Daly, in this village, bored 75 feet, obtaining no water. The North Branch of Two Rivers supplies the water used here, which is healthful, but very hard. A mile west of Northcote a salt spring issues in the bed of this stream. Salt springs also occur in the channel of the South Branch of Two Rivers, about 5 miles west of Hallock.

Humboldt.—The section of the deep artesian well on the farm of D. H. Valentine, at this station, has been given on page 75, and an analysis of its water on page 537. This water has never been utilized.

St. Vincent.—A well 165 feet deep was bored by the railway company about three-fourths of a mile east of St. Vincent in the winter of 1878–79. It yielded very saline water, not used, which rose 10 feet above the surface. The section was alluvial clay and till to the depth of 120 feet, and gravel and sand thence to the bottom, 45 feet.

The common wells of this county are 10 to 30 feet deep, generally obtaining water which is slightly alkaline, but may be used for all farm and domestic purposes, if the wells are drawn from plentifully so as to insure new inflow every day.

WELLS ON THE AREA OF LAKE AGASSIZ IN NORTH DAKOTA.

RICHLAND COUNTY.

Wahpeton.—No artesian water was found in a boring 120 feet deep at the Richland County court-house, the section being till, which incloses thin layers of sand and gravel. A deeper boring passed through the drift to Cretaceous shale, probably the Fort Benton formation, at 195 feet.

The city is furnished with water by a system of waterworks, which pumps its supply from the Red River, above Breckenridge, at the upper end of a long ox-bow or horseshoe-like circuit of the river.

Fifteen or more flowing wells are reported in the German settlement along the Wild Rice River, within 10 miles southwest of Wahpeton, ranging in depth from 70 feet to 305 feet.

Farmington.—A. D. Ellsworth, 1 mile southwest of Farmington station: Flowing well, 93 feet deep, almost wholly in till; water of good quality, called "soft," rises 7

feet above the surface. There are several other flowing wells of similar depth in this vicinity.

Fairview.—On the Fairview Farm an artesian well 240 feet deep, bored wholly in alluvial, lacustrine, and drift deposits, has a powerful flow.

Mooreton.—Artesian wells at the Mooreton Roller Mills and at the Central Hotel are about 135 feet deep, obtaining moderate flows of good water, about 4 gallons per minute from an inch pipe.

On the Minneapolis Farm, owned by Bull & Menage, about 2 miles northwest of Mooreton, a well 150 feet deep flows 7 gallons per minute from a three-fourths inch pipe. At 11 feet above the surface it shows no perceptible decrease in the force of the flow.

The Antelope Farm, owned by Hugh Moore, about 3 miles farther northwest, has an artesian well 173 feet deep, with two-thirds as strong flow as the last.

Wyndmere.—The Northern Pacific Elevator Company bored to the depth of 267 feet, obtaining no artesian water. The thickness of the alluvial, lacustrine, and drift formations was in total 218 feet, below which the boring went 49 feet in dark Cretaceous shale.

Dwight.—Ten artesian wells, from 85 to 105 feet deep, are within a radius of 5 miles around this village. Their water is good, not at all saline, but slightly alkaline, though less so than that of the common wells, which are 10 to 25 feet deep.

Colfax.—H. E. Crandall, Headquarters Hotel: Artesian well, 85 feet deep; soil and delta sand, 6 feet; till, 79 feet, to sand and gravel at the bottom.

Depths of other artesian wells in Colfax village, all obtaining good water in the drift, are as follows: At Cargill Bros.' elevator, 125 feet; at the Red River Valley mill, 128 feet; and at the railway tank, 135 feet.

Two flowing wells, 55 and 60 feet deep, are reported within a few miles east of this village.

Walcott.—Minnesota and Dakota Elevator Company: Flowing well, 120 feet deep; the water, which is of excellent quality, rises only 1 foot above the surface.

The artesian town well, 25 rods east of the preceding, is 110 feet deep. It ceases flowing when the larger pipe of the elevator well, 4 inches in diameter, is opened to its full size.

An artesian well 1 mile north of Walcott, 227 feet deep, obtains good water, called "soft," which rises only to the surface. About 2 miles farther north a well 104 feet deep flows about 50 barrels daily, rising 5 feet above the surface. Another flowing well, 2 miles north of the last, is 131 feet deep.

Common wells in all this region obtain ample supplies of water at depths ranging from 10 to 30 feet, and no salt taste is noticeable in the water of either the common or the artesian wells.

CASS COUNTY.

Kindred.—No artesian wells. The common wells are 10 to 15 feet deep, in fine loamy silt, obtaining slightly alkaline water from a layer of sand 1 foot thick at the bottom.

Davenport.—The town well is 70 feet deep, in alluvial and lacustrine beds, and has about 10 feet depth of water. Several other wells in this village are similar; none artesian.

Leonard.—Wells here, on the Sheyenne delta of Lake Agassiz, obtain a copious supply of excellent water at 18 to 20 feet. The section is all sand, which continues beyond the depth of the well bored or driven 46 feet by the Northern Pacific Elevator Company.

Warren.—At the buildings of the Leech Bros.' farm, in the southeast quarter of section 17, a boring 475 feet deep, finding no artesian water, went through the lacustrine clay, till, and probably a considerable thickness of Cretaceous shale; and its lowest 75 feet were in a fine white sandstone, very hard and compact, doubtless the Dakota sandstone, which here, as occasionally farther north, is so close grained in its upper portion as to be almost impervious to water.

Durbin.—Cargill Bros.' elevator: Artesian well, 160 feet; water chalybeate, at first a copious flow, diminished later by sand filling the lower part of the pipe.

Common wells in this village and its vicinity are about 30 feet deep.

Everest.—At the Cargill Bros.' elevator a well 160 feet deep derives water from gravel at the bottom, rising nearly to the surface. The common wells are 40 to 50 feet deep, with good water from gravel, filling the wells to the depth of 20 to 30 feet.

Gill.—An artesian well on the farm of J. C. Gill, in the northwest quarter of section 35, is about 260 feet deep, with water rising 15 feet or more above the surface.

Fargo.—The alluvial and lacustrine beds and the glacial drift are together 220 feet thick, being, in descending order, stratified clay, 95 feet; sand and gravel, 10 feet, yielding water which rises nearly to the surface; and till, 115 feet, inclosing occasional layers and veins of water-bearing sand and gravel. Below the drift a boring went 42 feet farther, probably in Cretaceous strata referable to the Fort Benton formation, being soft, dark blue shale, 32 feet; coarse sand rock, 6 feet; and a second shale, 4 feet, in which the boring stopped at a total depth of 262 feet. Water rose from the sand rock to 10 or 12 feet below the surface, apparently a good supply.[1]

Pillsbury & Hulbert elevator: Well, 150 feet; water rises to 8 feet below the surface, in so copious supply that it can not be lowered by pumping; it is of excellent quality, softer than the water of the river.

Most of the water used throughout the city is taken from the river by a system of waterworks.

[1] U. S. Geol. Survey of the Territories, 1872, p. 301.

Mapleton.—Wells in this village are 60 to 80 feet deep, in alluvial and lacustrine clayey silt, obtaining slightly alkaline water from sandy beds at the bottom, whence it rises to be 30 to 40 feet deep.

Dalrymple.—Cass & Cheeney Elevator Company: Well, 60 feet; water seeps, scanty, alkaline.

Casselton.—The city artesian well is 327 feet deep, its section being yellowish alluvial clay, 25 feet; darker bluish clay and sand, alluvial and lacustrine, 45 feet; till, 180 feet, inclosing thin seams and veins of sand and gravel; and very fine-grained sandstone, probably the Dakota sandstone, in some portions containing fragments of lignite, 77 feet, in which the boring ceased. The same section, to the depth of 317 feet, was also found by the well at Capt. C. May's flouring mill. Both these wells obtain slightly brackish water, which rises 40 feet above the surface.

Smith Stemmel, 3 miles west of Casselton, has a similar flowing well about 350 feet deep.

Northern Pacific Elevator Company: Well, 100 feet; water, somewhat saline, rises from a layer of sand to 6 feet below the surface.

The common wells of Casselton and its vicinity vary in depth from 20 to 70 feet, the deepest obtaining good water at the top of the till, whence it usually rises to fill the lower half of the well.

Wheatland.—Slightly alkaline water is supplied by most of the wells in the village, which are 20 to 30 feet deep in till; but water of excellent quality is obtained on the Campbell beach, in the east edge of the village, by wells 15 to 20 feet deep in the beach gravel and sand.

Tower City.—The city artesian well has been described on page 535.

Reed.—C. H. Welton, southeast quarter of section 17: Flowing well, 153 feet deep, in alluvial and lacustrine deposits for its upper part, with much till below. Water, fresh, and soft enough for washing with soap, rises 4 feet above the surface.

B. P. Reynolds, northeast quarter of section 20, about 40 rods southeast from the last: Well, similarly flowing, only 130 feet deep. Probably these two wells are supplied by separate water-bearing layers.

Raymond.—E. Porrett, southwest quarter of section 6: Well, 80 feet, in alluvial clay and till, the latter containing fragments of lignite; the water, somewhat alkaline, rises to 1 foot below the surface.

H. G. Roberts, in the northeast quarter of section 23, close north of the Maple River, has a flowing well 190 feet deep.

Harwood.—Minneapolis and Northern Elevator Company: Flowing well, 117 feet deep; water rises from sand and gravel to 10 feet above the surface; it is fresh, good for drinking, and called "soft" for washing.

Argusville.—The Minneapolis and Northern Elevator Company has three artesian wells, one 158 feet deep; another, 20 feet distant, 157 feet; and a third, about 35

rods distant, 147 feet. Below a small depth of alluvial and lacustrine clay these go through till with bowlders. The water, very good for drinking, comes from a bed of gravel and sand 5 to 7 feet thick, which was passed through to till beneath in one of these wells.

Berlin.—Two flowing wells in the northeastern part of this township are 87 feet and about 100 feet deep. The common wells are 40 to 60 feet deep, with water rising to 10 or 15 feet below the surface.

Amenia.—The artesian well at the elevator of the Amenia and Sharon Land Company is 279 feet deep; water rises 5 feet above the surface, not a copious flow. Another boring went to the depth of 400 feet, finding no lower artesian water. The section was soil, 2 feet; yellowish gray till, 30 feet; harder dark bluish till, about 200 feet, inclosing occasional water-bearing layers of sand and gravel; and Cretaceous beds below, the last 100 feet or more being very fine-grained white sandstone and nearly white shale, probably the Dakota formation.

Edward McNeill, a half mile east of Amenia, has an artesian well 215 feet deep, yielding a large supply of water. On Lee E. Clark's farm, some 4 miles distant to the northeast, the copiously flowing water of a well about 275 feet deep rises 30 feet above the surface. All these deep wells at and near Amenia have slightly brackish, hard water.

William Hinkle Smith, in section 32, has bored 290 feet, obtaining no artesian water. The well most used by this large farm is 75 feet deep, with a very abundant supply of good water, which rises to 20 feet below the surface.

On the farm of Gage & Davis, in the southeast quarter of section 9, a well 155 feet deep has water which rises from the bottom to 5 feet below the surface. This water, like that of Mr. Boustead's well, noted on page 553, contains gas which is not visible when the water first flows from the pump, but shows in very minute bubbles, as fine as dust, from one-fourth to three-fourths of a minute later, then disappearing so that the water is left clear. It is called excellent water for drinking and for engine boilers.

Ripon.—A railway boring to the depth of 280 feet found no artesian water. Common wells mostly are 20 to 40 feet deep, obtaining a copious supply from sand and gravel beds inclosed in the till.

Gardner.—Minneapolis and Northern Elevator Company: Well, 125 feet; water rises 12 feet above the surface.

S. C. Dalrymple, section 6: Artesian well about 230 feet deep; strong flow. There are ten or more other flowing wells within a few miles around Gardner, ranging from 96 feet to 250 feet in depth. Their water is slightly brackish.

Grandin.—The village of Grandin has four artesian wells within an extreme distance of 50 rods from east to west and half as much from south to north, as follows: William Black, 105 feet deep, with water at first rising 12 feet, now 8 feet; the

Grandin Hotel, P. C. Weisbecker, 158 feet, water rising 15 feet; the Minneapolis and Northern Elevator Company, 187 feet, water rising 12 feet; and J. W. Thom, at his store, 248 feet, water rising only 2 feet. All these wells are slightly saline, but are called good for drinking and cooking, except in making tea. It is remarkable that they obtain water at four distinct levels, showing that at least the upper water-bearing deposits of gravel and sand are narrow veins, as of stream courses; or, if they form broad sheets, those above are pinched out in places, so that the deposits of overlying and underlying till come together. (See pages 525, 526.)

TRAILL COUNTY.

Elm River.—Robert Young, about a mile west of Quincy, has an artesian well 213 feet deep; water copious, slightly saline.

Alexander Armstrong's well, a half mile south of Mr. Young's, is 110 feet deep, with very strong flow, having scarcely any perceptible saline taste.

Kelso.—St. Anthony and Dakota Elevator Company: Well, 110 feet; mostly in till, below a considerable thickness of alluvial and lacustrine clay; water at first overflowed, but now stands a few feet below the surface; it is capable of supplying 200 barrels in twelve hours, the diameter of the pipe being 2 inches.

Minneapolis and Northern Elevator Company: Well, 109 feet; water overflows slightly; ample supply for pumping. The water of both these wells is slightly salty, but is not harmful for drinking; it rapidly rusts through the plate of engine boilers in which it is used.

James Johnson, section 3: Artesian well, 175 feet deep; the water flows from the pipe, which is 2 inches in diameter, at the rate of about 2 barrels per minute, forming a considerable brook; when confined in the pipe, it rose 20 feet above the surface, and flowed with little apparent diminution. The water is saline, but both cattle and people prefer it rather than the water of the adjoining creek, the North Branch of the Elm River. This well was bored only about 150 feet deep, the section having been nearly all till; then, within fifteen or twenty minutes, the pipe sank about 20 feet in quicksand, and it settled more during the following night. When the sand filling the lower part of the pipe was cleared out, the water rose with such force as to bring up gravel stones from 1 to 1½ inches in diameter in the 2-inch pipe, showing that it had sunk to a bed of gravel. In this well a feeble artesian flow was noted at about 110 feet, as in the wells of Kelso village, 1½ miles distant. There are several other flowing wells within 1 or 2 miles around Mr. Johnson's, some being about 110 feet deep, and others having nearly the same depth as his well.

S. A. Dalrymple, southeast corner of section 1: Artesian well, 180 feet deep; 2-inch pipe, flowing a stream a half inch in diameter at 3 feet above the surface; water slightly brackish.

Alexander Smart, southeast quarter of section 12: Boring 417 feet deep, obtaining no artesian water; the alluvial and lacustrine beds of the surface have an undetermined thickness, probably less than 60 feet; next below, till extends about 250 feet, inclosing occasional thin beds of sand and gravel, to the base of the drift at 310 feet. Thence the boring went 107 feet in a very fine-grained white sandstone, in part very hard, but in other parts less so than the till. The drillings from this formation, believed to be the Dakota sandstone, are mostly similar to flour in their fineness, but usually they also contain many small, rounded quartz grains, from a hundredth to a fiftieth of an inch in diameter.

Bohnsack.—R. M. Cunningham, southeast quarter of section 5, township 144, range 52: Well, 140 feet deep, wholly in till; water rises from sand and gravel at the bottom to 30 feet below the surface.

Hague.—On Farm No. 1 of the Grandin and Dalrymple Farming Company, at Hague post-office, northwest quarter of section 25, township 145, range 49, are two artesian wells, 160 feet and 210 feet deep; water, slightly saline, rises from each to a height of 10 feet or more above the surface. The well on Farm No. 3, in the northeast quarter of section 9, township 144, range 49 (Elm River), is 160 feet deep, with water rising just to the surface. From another artesian well, on Farm No. 6, in the southeast quarter of section 33, township 145, range 49, also 160 feet deep, the water rises 6 feet.

Hillsboro.—In the city of Hillsboro and within a distance of 5 miles there are probably thirty or more artesian wells, mostly between 100 and 200 feet deep, all obtaining somewhat saline and alkaline water. Notes of several in Hillsboro are as follows:

W. H. York, in the northeast part of the city: 105 feet deep; flow about 200 barrels daily; water slightly brackish, softer than the water of the deeper wells.

City well, at the intersection of the two principal streets: 185 feet deep; flow about 75 barrels daily, through 6-inch pipe; strongly brackish, used only for watering horses and cattle.

S. C. Sherwood, in the north part of the city: About 190 feet deep; flow estimated at 400 barrels daily, through 2-inch pipe. The water of this well, with largest flow in the town, though salty, is employed for all uses of the house and stable, including drinking and cooking. But in general throughout the city the principal supply for domestic uses is taken from the Goose River.

Minneapolis and Northern Elevator Company: 195 feet deep.

J. R. Nunn's livery stable: 198 feet deep.

Florence Mill Company: 195 feet deep; flow, 250 barrels daily.

At the North Dakota Roller Mill, in the south part of the city, several borings have been made, in all of which combustible gas has been found at the depth of 105 to 120 feet. The deepest of these borings went 630 feet, obtaining no artesian water.

A considerable thickness of Cretaceous beds, apparently the Fort Benton shales and the Dakota sandstone, were penetrated, reaching "quartzite" at 620 feet.

Blanchard.—Again, probably as many as thirty artesian wells exist in Blanchard village and within a radius of 5 miles around, varying in their depth from 150 to 404 feet. The glacial drift extends to a depth of about 200 feet, below which these wells pass into Cretaceous shale and very fine-grained sandstone, probably the Dakota formation. The following are two of the deepest borings:

S. S. Blanchard, section 11, township 145, range 52: Well, 375 feet; brackish water, good for stock throughout the year and used in engine boilers, rises 15 feet above the surface.

Emerson & Wild, southwest quarter of section 19, township 145, range 51, a half mile north of Blanchard Village: Well, 404 feet deep; brackish water, capable of rising 40 feet or more above the surface, flows at the rate of 30 gallons per minute from a 2½-inch pipe.

Norman.—On Jones & Brinker's farm, in section 13, an artesian well about 350 feet deep has a strong flow of saline water.

Mayville.—Goose River Mill, owned by Gibbs & Edwards: Artesian well, 395 feet deep, in drift about 200 feet and below in Cretaceous shale and sandstone; water brackish.

The city artesian well, 355 feet deep, has a strong flow of brackish water, which rises 22 feet above the surface, its rate of flow being about 85 gallons per minute.

Common wells in Mayville and its vicinity are 20 to 40 feet deep, in alluvial clayey silt and till, obtaining somewhat alkaline water. The supply needed for drinking and cooking is taken from the Goose River, excepting by those who have rain-water cisterns.

Portland.—A boring for the railway tank is said to have gone to the depth of 275 feet, obtaining no artesian water.

Minnesota and Dakota Elevator Company: Well, 90 feet; water rises to 20 feet below the surface; it is brackish, and forms much scale on the boilers of engines.

The common wells in Portland are 15 to 40 feet deep in till, from which water seeps, somewhat alkaline.

Hatton.—Cargill Bros.' elevator: Well, 254 feet; delta silt, about 20 feet; till, inclosing occasional sand and gravel layers, about 200 feet; and sand, 34 feet. Excellent water, which makes but little scale on the engine boilers, rises to 6 feet below the surface.

Common wells here are only 10 to 12 feet deep, obtaining plentiful and good water in the fine sand of the Elk Valley delta.

About 3 miles southwest of Hatton, in section 25, Newburg, Steele County, a boring on the farm of Smith & Mills went to the depth of 553 feet, obtaining a strong artesian flow, which, however, soon ceased because the lower part of the pipe became

filled with sand. The bottom of this boring is at nearly the same elevation above the sea as that of the deep artesian wells of Blanchard and Mayville, being, like them, doubtless, in the Dakota sandstone.

GRAND FORKS COUNTY.

Northwood.—Red River Valley Elevator Company: Well, 20 feet deep, in delta sand; water usually 10 to 15 feet deep, overflowing in the spring. Common wells here are 15 to 18 feet deep, supplying good water, which forms little scale on engine boilers.

Kempton.—Wells in the vicinity of Kempton are about 20 feet deep, the section being soil, 2 feet; fine clayey sand, 10 feet; a harder bed of sand, 2 feet; and quicksand below, which contains an ample supply of excellent water.

Grand Forks.—A railway well bored near the depot in 1881 to the depth of 265 feet, 5 inches in diameter, reduced below to 3½ inches, yielded in August of that year, probably after the lower part of the pipe had become filled with sand, only a very scanty overflow; water saline, not used.

C. J. Alloway, in the north edge of the city: Artesian well, 270 feet; alluvial and lacustrine clay, 30 feet; till, inclosing occasional beds of sand and gravel, 220 feet; and sand, 20 feet; the water, too saline to be used, rises 2 feet above the surface.

The common wells of Grand Forks, 20 to 30 feet deep, have water of fair quality, but the city is mainly supplied through waterworks which pump from the river.

Brenna.—Lawrence Kennedy, in the north part of this township, about halfway between Grand Forks and Ojata, has a flowing well of brackish water 90 feet deep.

Ojata.—Minneapolis and Northern Elevator Company: Flowing well, 115 feet deep; water saline, unfit for engine boilers, though it has been so used. Similar artesian water was also found by this well at the depth of about 70 feet. Common wells are mostly 15 to 18 feet deep, obtaining water that is slightly alkaline, though not perceptibly so to the taste. When dug deeper they get bitter or salty water.

Emerado.—Wells in this village and its vicinity are 15 to 20 feet deep, in till, with thin veins and layers of sand; good water. One well, bored 70 feet deep, near the depot, found no water supply, while another well 10 rods east found plenty of water at 20 feet.

The well of the railway tank was dug 53 feet deep in a dry season, and the workmen at night left their tools at the bottom, which gave no sign of water; but the next morning it was full of water to 8 feet below the surface.

Arvilla.—Common wells at and near Arvilla are 15 to 30 feet deep, in till, obtaining somewhat alkaline water. The first boring for a town well went nearly 200 feet in the till, obtaining no sufficient water supply. A second boring found abundance of good water at 85 feet, whence it rises to about 30 feet below the surface and is not lowered by vigorous pumping.

Larimore.—The well at the Sherman House, 60 feet deep in the fine silt and sand of the Elk Valley delta, and other shallower wells, are noted on pages 334, 335. The water is copious and of good quality, forming little scale on engine boilers.

Manvel.—Joseph Colosky, Manvel Hotel: Artesian well, 166 feet deep, in alluvial and lacustrine silt and till, inclosing occasional layers of sand and fine gravel. A large flow of saline water was found in such a layer at 107 feet. The second flow, at 166 feet, is very strong, running from the 2-inch pipe at the rate of about 40 gallons per minute.

Minneapolis and Northern Elevator Company: Artesian well, 175 feet; the water is capable of rising more than 45 feet above the surface, there flowing from an inch pipe (reduced from the diameter of the well, which is 2 inches) at the rate of about 6 gallons per minute. In 1887 this well had been running five years and showed no diminution of flow. The water contains much sulphate of magnesia, not being so salt as that at 107 feet. In engine boilers it forms a powdery precipitate, which is easily blown out by the engineer, not being so troublesome as the usual scale.

Turtle River.—Richard Forrest, northeast quarter of section 28: A boring, seen when it was in progress at 150 feet, had brackish artesian water flowing feebly from sand all the way below 100 feet.

Johnstown.—William Stratton, section 22: Well in alluvial clay, which at the depth of 19 feet contained a log 10 inches in diameter, thought to be birch. It was chopped off to permit the well to go deeper. Another well in the southwest part of this township found two similar tree trunks 16 feet below the surface.

WALSH COUNTY.

Ardoch.—Minneapolis and Northern Elevator Company: Artesian well, 164 feet, the section being mostly till; large flow of saline water.

Brooks Bros.' elevator: Well, 42 feet deep, 8 feet in diameter, with plenty of water. A boring below this to the total depth of 100 feet from the surface was stopped by a bowlder. The section was alluvial clay, 15 feet; sand and gravel, ½ foot; and till, easy to dig and bore, 85 feet. Alkaline water seeps, much coming from the gravel at 15 feet.

Common wells at Ardoch are 15 to 20 feet deep, most of them obtaining tolerably good water. The town has two public wells or cisterns, each 13 feet deep and 13 feet in diameter, and another measuring 15 feet in these dimensions, for fire protection.

Minto.—Minneapolis and Northern Elevator Company: Artesian well, 200 feet deep; alluvial, lacustrine, and drift deposits, 190 feet, the lower two-thirds being till, with no important water-bearing veins or layers; then sand and gravel, 10 feet and extending below. The water rushed up with such force as to bring pebbles an inch in diameter, and rises when confined in pipes to a height of 60 feet above the surface.

It is quite brackish, but some persons have drunk it freely and almost solely during several years, thinking it favorable for their health.

Brooks Bros.' elevator: Well, 196 feet deep, with similar strong flow as the foregoing.

The common wells are 15 to 20 feet deep, in yellow alluvial clay, to blue clay which is not dug into; water seeping, slightly alkaline.

Grafton.—The deep artesian well of the city, passing through Lower Silurian strata below the drift, and obtaining a powerful flow of brackish water, has been described on pages 77, 78.

The Minneapolis and Northern Elevator Company and the Brooks Bros.' elevator had artesian wells, each 156 feet deep, but their water was so saline and scanty that they are disused.

The water of the common wells here, 12 to 25 feet deep, is slightly alkaline, but is considered healthful.

About 5 miles northeast of Grafton a well is reported to have found in the alluvial clay, at the depth of 35 feet, a log about a foot in diameter, which was chopped off at both sides of the well.

Conway.—The depths of the common wells range from 20 to 60 feet, in till.

Park River.—Wells 15 to 40 feet deep, in till, obtaining a plentiful supply of good water.

PEMBINA COUNTY.

St. Thomas.—Minneapolis and Northern Elevator Company: Artesian well, 175 feet deep, mostly in till; water saline, but used in the engine boiler. The Brooks Bros.' elevator is supplied by a well only 18 feet deep.

The common wells are 15 to 20 feet deep, in alluvial clay; water slightly alkaline.

Glasston.—The Minneapolis and Northern Elevator Company has a flowing well about 200 feet deep, with water rising only 2 feet above the surface, but yielding an inexhaustible supply when pumped. It is brackish, but is drunk freely by stock and by some people, who soon like it, and no injurious effects attend its use.

Common wells, mostly 14 to 20 feet deep, have somewhat alkaline water. Several other wells within a few miles east of the railway between St. Thomas and Glasston, and about the latter station, go 90 to 150 feet through till to gravel and sand, from which water, slightly brackish, rises immediately to a permanent level 10 to 20 feet below the surface.

Hamilton.—Minneapolis and Northern Elevator Company: Artesian well, 179 feet; water brackish.

Rand & Norton's livery stable: Artesian well, 175 feet; also brackish, but agreeing with horses and cattle.

The common wells of Hamilton are 12 to 20 feet deep, usually having good water. Many other wells have been bored in this vicinity 75 to 150 feet deep, only

rarely obtaining artesian flows; but water, found in gravel and sand at the bottom generally rises nearly to the surface. In some wells the water is too salty or bitter to be used, but others equally deep have fresh water. The former probably derive their water supply from great distances through beds of sandstone underlying the drift, while the latter receive their water from rains on neighboring areas, percolating only through porous sand and gravel beds of the drift sheet.

Bathgate.—The artesian well of the Minneapolis and Northern Elevator Company is 143 feet deep, passing through alluvial and lacustrine clay and till to coarse sand, whence a very copious flow of water rises to 6 feet above the surface. It is somewhat saline and alkaline, but its mineral matter is chiefly deposited as a powdery sediment in the boilers of engines, which can be easily blown out.

During the year 1887 eleven artesian wells, ranging from 130 to 160 feet in depth, were bored within a radius of 5 miles about Bathgate.

There are no shallow wells in this town, as the seeping surface water is too alkaline. The water of the Tongue River is used for ordinary domestic purposes.

Neche.—Minneapolis and Northern Elevator Company: Well, about 175 feet deep; water saline, rising to a few feet below the surface; unfit for any use.

Akra.—Abner French, at center of section 18, township 161, range 55, 6 rods southeast of the Tongue River: Well, dug at first about 16 feet deep, having good water, which seeped from the alluvial clay. In an unusually dry season it was dug 4 feet deeper, and found a layer of sand from which water of inferior quality soon rose 6 feet, to the level of the river.

WELLS ON THE AREA OF LAKE AGASSIZ IN MANITOBA.

Artesian or flowing wells are obtained at many localities in Manitoba near the Red River, as in Winnipeg and southward, where water often rises to the surface from layers of sand and gravel in the drift.

Winnipeg.—About 40 wells have been bored by the city authorities of Winnipeg, for supplying water for domestic use. Mr. H. N. Ruttan, the city engineer, states that about a dozen of these wells go into the bed-rock, which is limestone, while the others derive their water from layers of quicksand in or beneath the till. Several of them in the west part of the city are artesian, but eastward the water rises only to 5 or 10 feet below the surface. The water is considered of good quality for drinking and cooking, but it contains much mineral matter in solution, chiefly the sulphates of lime and magnesia.

Alluvial stratified clay extends to a depth that varies from 3 to 10 feet or more. This is underlain by the glacial till or bowlder-clay, which incloses thin veins and layers of fine gravel and sand, and frequently is underlain by sand and gravel, but in many places extends to the limestone. The upper part of the till here shows an imperfect stratification, due to its deposition in Lake Agassiz, and contains a less

proportion of bowlders and gravel than its lower part, which is very hard, and is therefore commonly denominated "hardpan." The depth to the limestone varies from 30 to 60 feet in the west part of the city, and increases to about 75 feet eastward.

One of these wells, bored in the west edge of the city, close north of the Assiniboine and 1½ miles west of the Osborne street bridge, went 32 feet in stratified clay and till, and then 100 feet in limestone, mostly of light buff or cream color, obtaining water of good quality at 132 feet, which rose to 5 feet below the surface. The bed-rock is nearly like that which outcrops at Lower Fort Garry and East Selkirk.

A general section of the superficial deposits at Winnipeg is noted by J. Hoyes Panton as follows, from information supplied by Mr. Piper, known as having an extensive experience in well boring throughout the city:

1. Surface mold, 1 to 4 feet thick, dark color, and exceedingly fertile.
2. "Yellow gumbo," 2 to 3 feet; a very sticky form of yellowish clay, which usually holds considerable water.
3. Dark gray clay, 30 to 50 feet thick, with bowlders scattered throughout, some of them 4 feet in diameter and chiefly gneissoid, and no doubt derived from Laurentian rocks.
4. Light-colored clay, 1 to 3 feet, containing many small stones.
5. Hardpan, 2 to 10 feet, a very solid and compact form of clay.
6. Sand, gravel, and bowlders, 5 to 25 feet.
7. Angular fragments, 1 to 3 feet, usually limestone, and largely derived from the solid rock which lies immediately below it.

This loose material is far from being uniform, and varies so much in its arrangements that scarcely any two borings show the same distribution. Sometimes there is little or no hardpan, while in other parts it is several feet thick. However, as a usual thing, these seven forms of strata are passed through in boring, and varying in thickness to the number of feet already mentioned.[1]

St. Boniface.—Wells in St. Boniface are nearly the same as in Winnipeg, on the opposite side of the river. The deepest learned of is on the exhibition ground, 156 feet deep, being stratified clay and till, 36 feet, its lowest 10 feet very hard and compact; sand, 44 feet, to the bed-rock at 80 feet; then limestone, of light cream color or nearly white, penetrated 76 feet and extending below.

Niverville.—Thomas W. Craven, hotel: Well, 65 feet deep, in alluvium and till; water rises to 15 feet below the surface. Other wells in this village have nearly the same depth or less, none coming to the bed-rock; but it was reached by a well a third of a mile east, at a depth of about 100 feet.

Four miles south-southeast of Niverville, in the northeast quarter of section 5, in this same township 7, range 4 east, Cornelius Freesen's well, situated on the Niverville beach, passed through alluvium and glacial drift, 65 feet, and shale, 30 feet, obtaining an ample artesian flow of excellent water.

In the southwest quarter of this section, a half mile from the foregoing, Adam Freesen has a similar flowing well, 107 feet deep, which went 37 feet into the shale.

[1] Report of the Department of Agriculture and Statistics, Manitoba, for 1882, p. 176.

This is said to be the deepest of about twenty flowing wells in this Mennonite Reserve, their range of depth being from 40 to 107 feet.

Dominion City.—James Spence, Victoria Flour Mills: Flowing well, 170 feet deep, in alluvial clay and till, the latter very hard below the depth of 120 feet; bed-rock not reached; water brackish, flowing feebly, not used.

The common wells of this village, 12 to 16 feet deep, have good water which seeps from the alluvial clay.

The Roseau River has much softer water than the wells and most of the short streams of this region, so that the railway tank at Dominion City, taking water from the Roseau, is preferred by the locomotive engineers above any other source of water on this branch line.

Emerson.—Wells in Emerson range from 10 to 25 feet in depth, in alluvial clay, and obtain water tolerably good for drinking and cooking, but it is very hard and unsuited for laundry use.

West Lynne.—Hudson Bay Company's steam flouring mill: Well, 108 feet deep, dug 68 feet in alluvial and lacustrine clay, and bored 40 feet lower, apparently in the same deposit. The only water found, not enough to supply the engine, is that which seeps from the clay, coming almost wholly within the first 20 feet below the surface. The ordinary wells in this village, 14 to 18 feet deep, obtain good water, seeping in sufficient amount for domestic use.

Artesian wells near Letellier and on the Low Farm.—An artesian well on the French Reserve at the center of township 2, range 1 east, near Letellier, 12 miles northwest from Emerson and West Lynne, is 250 feet deep, not reaching the bed-rock. It supplies brackish water, which is drunk by cattle. Another artesian well of similar depth is on the Low Farm, about 12 miles west of Morris, the water of which is strongly saline.

West Selkirk.—The well at the Lisgar House, 100 feet deep, reached the bed-rock, which is limestone, at 65 feet.

Stonewall.—J. B. Rutherford's flouring mill: Well, 82 feet deep, consisting of beach gravel and sand, 10 feet; till, 2 feet; and limestone, including red shaly beds, 70 feet, to the bottom, where the drill fell 1 foot and water rose immediately to 22 feet below the surface. Several other wells in Stonewall have had a similar experience, obtaining water which rises from hollows in the limestone.

Township 15, range 2 east.—William Andrew, southeast quarter of section 7: Well, 94 feet deep; till at the surface and to a depth of 11 feet; and limestone, 83 feet, mostly hard and of light buff color, but inclosing some 25 feet of reddish shaly beds between the depths of 45 and 70 feet. There are several such wells in the same vicinity.

Between Pleasant Home and Gimli.—Mr. Andrew states that about 25 miles northeast from the last a well between Pleasant Home and Gimli has been sunk 120 feet, wholly in the glacial drift, not reaching the bed-rock.

Rosser.—The railway well at Rosser is 29 feet deep, in till, which forms the surface there and east to Little Stony Mountain; water rises 15 feet from a sandy layer at the bottom.

Township 11, range 1 east.—Robert D. Bathgate, section 27: Well, 60 feet deep; till, 24 feet, from which alkaline water seeps; and light buff, hard limestone, 36 feet, and continuing lower; water of good quality rises from the bottom to 20 feet below the surface. Other wells in this vicinity mostly get good water in veins or thin layers of sand and gravel contained in the till.

St. François Xavier.—On Mr. Nanton's ranch, about 10 miles west of Headingly and a quarter of a mile south of the Assiniboine, a well 114 feet deep passed through alluvial clay, 14 feet; till, 34 feet; limestone of light cream color, 47 feet; and reddish limestone, 19 feet. Brackish water rises from the bottom to 14 feet below the surface.

Meadow Lea.[1]—Section 30, township 13, range 2: Wells in this vicinity range from 20 to 95 feet in depth, and are wholly in till, not reaching the bed-rock.

Township 13, range 6.—Charles Cuthbert, section 21, 10 miles north-northeast from Portage la Prairie: Well, 16 feet deep; soil and loamy silt, to water in quicksand and fine gravel. The surface here is only a few feet above the high-water level of Lake Manitoba.

Portage la Prairie.—The common wells are 12 to 16 feet deep, being black soil, 2 to 4 feet; then yellowish-gray, loamy silt, the alluvium of the Assiniboine, in which fragments of driftwood, as small limbs of trees, are occasionally found, to water in quicksand and fine gravel. The deepest well here is that of the Manitoba and Northwestern Railway tank, which reaches 30 feet, to till at the bottom, obtaining a very large supply of water.

Township 12, range 8.—Kenneth McKenzie, jr., in the north edge of section 2, close west of Rat Creek: Well, dug 86 and bored 72 feet, to a total depth of 158 feet; soil, 2 feet; sand, 4 to 5 feet; yellow till, 4 feet; blue till, 76 feet, easy to excavate, with scanty intermixture of gravel, but containing occasional stones up to 1 foot or more in diameter, undoubtedly true till, for the surface generally through the south part of this township has plentiful embedded bowlders up to 2 or 3 feet in diameter; below was "hardpan," a more indurated deposit of till, very hard to dig or pick, bored or drilled 72 feet, and found to vary much in its hardness through this depth, some portions being much softer than where the boring began. A seam of sand and fine gravel, about an inch thick, was noticed between the upper part of the till, which was dug, and the harder lower portion. At the bottom the drill struck a harder layer, which was called rock. It was probably shale, for the drill, being dropped a few times upon it, seemed in danger of becoming stuck so that it could not be removed. Water rose from the bottom within the first day to a depth of 20 or 30 feet in the portion of the

[1]Here and onward, through the following pages, the ranges are numbered westward from the reference meridian.

well that was dug, and within a few days it reached its permanent level, about 20 feet below the surface. It does not sink below this level in dry seasons, but in wet seasons it rises to 7 feet below the surface, near the bottom of the sand. It is somewhat salty, so that it is not suitable for house use, but it is drunk freely, and with no ill effect, by horses and cattle during the entire winter.

A quarter of a mile south of this Mr. McKenzie's father has a similar well as to its depth and succession of deposits passed through to rock, but it obtains a less ample supply of water. Both wells are 864 feet, approximately, above the sea; and the top of the bed-rock is accordingly about 706 feet above the sea-level.

Gladstone.—Wells vary from 10 to 15 feet in depth, in sandy, fine silt. Water abundant and of excellent quality.

Arden.—In the vicinity of Arden wells are 10 to 50 feet deep, the section being till, excepting where this is overlain by beach deposits from 5 to 15 feet thick.

Neepawa.—John A. Davidson & Co., store: Well, 60 feet, the deepest in the town; soil, 2 feet; gravel and sand of the Assiniboine delta, 12 feet; and till, dark bluish, with the usual proportion of gravel and bowlders, 46 feet, and extending below; water good. Other wells, mostly 15 to 25 feet deep, reach till at nearly the same depth.

Township 13, range 16.—The deepest wells in this township go 50 to 70 feet, wholly in till; but commonly a sufficient supply of water is found within 30 feet or less.

Carberry.—Wells 10 to 20 feet deep in sand, the Assiniboine delta; plenty of good water.

Chater.—At the elevator, 42 feet, and at the hotel, 31 feet, wholly in till, yellowish above and dark bluish below; water rose several feet.

Brandon.—Wells 10 to 30 feet deep, in delta gravel, underlain by till; good water.

Carman.—Depths 10 to 15 feet, in alluvial clay, with sandy layers; good water. Two miles south of Carman, James Stewart's and George E. Laidlaw's wells are, respectively, about 100 and 120 feet deep, probably passing through the alluvial and lacustrine clays and glacial drift to underlying Cretaceous shales. The water of the deeper of these is too brackish for house use, but is drunk by cattle.

Treherne.—In the vicinity of Treherne wells vary from 15 to 50 feet in depth, the section being beach and delta deposits of stratified gravel and sand; excellent water.

Holland.—Wells at Holland are 10 to 20 feet deep, in till to shale, which is reached at about 10 feet; water good, generally better from the shale than from the drift. Shale is not encountered by wells farther north, on the Assiniboine delta. In the adjoining Tiger Hills, on the south, the depth to shale varies commonly from 2 or 3 to 10 or 15 feet.

Cypress River and Glenboro.—Depths, 10 to 17 feet, in fine silt, the delta of the Assiniboine; water good, issuing from quicksand.

Township 8, range 18.—Rounthwaite post-office, section 14: Well, 20 feet deep; soil, 2 feet; yellowish gray till, 13 feet; harder blue till, 5 feet and lower; water seeps, plentiful and good.

Township 7, range 17.—Williamson, Dignum & Co., farmhouse in section 3: Well, dug 30 feet and bored 32 feet more; seen while the boring was in progress at depth of 62 feet; all till, mostly yellowish, to that depth. This is half a mile north of the northern base of the Tiger Hills, at an elevation of about 1,350 feet above the sea.

Langs Valley.—Langvale post-office, at James Lang's house, section 2, township 6, range 18: Well, 18 feet deep; all gravel and sand, with quicksand at the bottom. This is on the bed of the channel of outflow to the Pembina from the glacial lake in the Souris basin.

Plum Creek.—Wells in this village, at the junction of Plum Creek with the Souris, are 10 to 30 feet deep, in till, not reaching bed-rock; but outcrops of the Fort Pierre shale occur on the Souris, near by.

Gretna.—Common wells, 10 to 20 feet deep, in alluvial and lacustrine clay, obtaining a scanty supply of water. A boring is said to have been made here for the railway tank, to a depth of 150 feet, without finding a supply of water, and it is now pumped from the Pembina River.

Rheinland.—Wells 15 to 20 feet deep, in somewhat sandy lacustrine clay; excellent water.

Township 2, range 5.—John Johnston, section 3: Well, 22 feet; soil, 2 feet; yellowish till, containing bowlders up to 5 feet in diameter, 20 feet; to gravel with water which rises from it 2 or 3 feet. This is between the Campbell and Tintah beaches, on the low terrace at the foot of the Pembina Mountain escarpment. Other wells near show that this terrace consists of the Fort Pierre shale, thinly covered with glacial drift.

Morden and Nelson.—The deep boring recently made unsuccessfully for artesian water at Morden has been described on page 81.

Common wells in Morden and Nelson are 10 to 25 feet deep, in alluvial silt and underlying till; water frequently alkaline.