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# The Geology of the Artesian Basin in South Dakota

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THE GEOLOGY OF THE ARTESIAN BASIN IN SOUTH DAKOTA.—*D. S. McCaslin.*

The artesian basin in South Dakota comprises an area variously estimated from 15,000 to 20,000 square miles. Its boundaries are not yet fully made out. It certainly extends from Yankton to Devil's Lake. Its eastern limits are marked by an irregular line running north and south, at a distance ranging from five to fifty miles east of the James river. Its western boundary is not yet defined. Its probable extension beyond the Missouri river is one of the strong conclusions of all the investigations, though it is doubtful if volume and pressure continue as great as we go toward the Black Hills. As yet no well has been put down west of the Missouri, except at Fort Randall which lies so far south and east that it has no practical bearing on the question of the western limit of the artesian basin.

The topography of this region is very simple. The James river lies in a broad valley of erosion from 50 to 60 miles wide, lying at an altitude above the sea ranging from 1,408 feet at Jamestown to 1,196 at Yankton. The railway track at Huron is 1,287. This would be about the average elevation of the valley through which flows the longest unnavigable stream in the world. From source to mouth, about 250 miles, yet its vermicular channel winds through more than 700 miles in persistent sinuosity. The present river is a mere trickle of the ancient flood that poured down this valley. The canal-like channel simply moves from side to side in a sluggish flow over an alluvial bed. Its banks vary from lacustral sedimentary deposits in Brown county, to bluffs of glacial drift, as in Beadle and Spink counties, till capped with modified drift in Beadle, Sullivan and Sanborn counties, the same covered with loess deposits as at Mitchell and southward. To the east or west of this river the altitude increases. At Arlington, about 45 miles east, it is 1,850 feet or 563 feet above level of Huron. At Highmore, about the same distance west, it is 1,890, or 603 feet higher than the James river. This outlines a great valley whose depression, by the way, bears no relation whatever to the artesian water. The water lies practically at the same level everywhere, as we shall see further on, and the differences of altitude only after the depth of the wells and not the deposit of the water. As I have intimated, the whole region is covered with drift deposits. But they are varied in character and distri-

bution. They are not uniform, either in thickness or material or in order of deposit.

The earlier observations of Todd and others on the drift of South Dakota inclined to the conclusion that the Coteau region west of the James river was analogous to that lying east, between the Sioux valley and the James. The observers found the drift deposits very heavy in eastern South Dakota, sometimes as thick as 250 or 300 feet, with the usual order of glacial material: a base of quicksand, overlaid by blue clay, with unpolished fragments of rock; above that till with polished bowlders inclined to stratification; over this assorted or modified drift, sand or gravel, with flow and plunge structure; over this sometimes loess or other sedimentary deposits. It is still a question in glacial study whether the later drift lies above the loess in South Dakota. (Chamberlain, Geology of Wisconsin, volume III, page 395.) This is the typical drift section. It is freely illustrated in the eastern Coteau region, but in the western we have very different conditions. The order of the eastern glacial deposits was carried by analogy to the western Coteau region. There was a similarity in outline and elevation. It was an easy and natural conclusion that the structure of the formation was the same. The fact is there is a marked difference in the drift of the Missouri Coteau and that of eastern portions of the state. In the first place the western deposit is very light as compared with that of the east. Rarely has the drift been found over 100 feet thick west of the James river. On the highest elevations east the drift is heaviest. On the highest elevation west it is lightest. At Helland, Kingsbury county, near Arlington—the top of the Coteau—it is 310 feet thick. At Harold, west of Highmore, in the valley of Medicine creek, the drift shows a thickness of but 125 feet. This is the heaviest typical drift section I have observed west of the James river. Seventy feet of this is blue clay.

Yet east, and south, and north of Harold are much higher altitudes where the drift is very light. At the very top of the Ree Hills the chalk is simply capped with a light deposit of morainic bowlders, yellow clay and gravel, with no blue clay. The same thinness of this deposit appears at Wessington Springs, where the "Cement rock" crops out within a few feet of the summit, with only a few feet of sand and gravel overlying. This point is fully 2,000 feet above the sea. This is the general state

of things west. The blue clay is frequently absent and the drift becomes only a thin sheet of bowlders and gravel. At Pierre it is very light, and at that particular point it does not cross the Missouri, though above and below it extends a few miles over on the reservation.

This observation on the real distribution of South Dakota drift will help us to see the position and relations of the underlying formations.

It shows us a heavy denudation of Cretaceous shales and chalks over all the Coteau region east of the James. If the "Cement rock" at the top of the Wessington Hills—2,000 feet above the sea—is Niobrara or Benton, either, its position shows a former wide extension eastward over all the region now where the drift lies directly on Pre-Cambrian rocks of either Algonkian or Laurentian age. It is a fact that the blue clays of this eastern portion are largely made up of disintegrated Cretaceous shales, and that this material below carries most of the fossil Baculites and Belemnites, while the upper morainic material carries quantities of diorite and syenite bowlders, with occasional slabs of limestone, many of them massive, and carrying characters of Silurian and Cambrian (?) fossils. One lying at the top of the Wessington Hills, 500 feet and more above the plain, will weigh more than 30 tons, and lies directly on a bed of fine ripple-marked sand. How a fact like that would have made the iceberg champions smile 10 or 20 years ago! We have got now where we can look at "both sides of the shield," and the berg of silver and the glacier of gold belong to the same scientific armor of truth.

We come now to the underlying geological section of the Artesian basin. The facts are fairly well made out. We know that the Pre-Cambrian rocks occupy wide areas beneath the heavy drift of the eastern Coteaus. Southward it is always Huronian quartzyte which crops out in force in all the lower Sioux valley, from Dell Rapids to Sioux Falls, westward in the Vermillion valley this same quartzyte appears at the surface. Outcrops are found in McCook and Turner counties, and also on Firesteel creek, near Mitchell. There is probably a heavier westward extension of this formation than was supposed. The fact is, all the borings show that both the granite and quartzite have a wider western area than was suspected. It is more than likely

that the Dakota sandstone lies on quartzite or granite from Yankton to Jamestown and not on Jura-Triassic rocks.

Here are a few of the facts: at Vermillion quartzite was reached at 630 feet below the surface; at Mitchell, 645 feet (with light flow); at Plankinton, 760 feet (this lies west of James river); at Tyndall, 735 feet; at Scotland, 548 feet; at Vilas, 462 feet; at Iroquois, 1,098 feet (147 feet above Hume); at Hume, 802 feet; Aberdeen, 955 feet. (Stopped at hard bottom.) This last is either granite or quartzite, probably the former.

This wide projection of these formations westward is along the trend of the great Pre-Cambrian systems that stretch from Lake Superior across Minnesota, and far into southeastern South Dakota. Why is this idea not the key to the peculiar distribution of the drift in the Dakotas? If the theory of a series of centers of glaciation is true why may it not be that the ice mass moved from North Minnesota southwestward, rather than from the Turtle Mountain country or Lake Winnipeg? That would put the heavy moraine in the right place across the Dakotas, and account also for the Laurentian bowlders in the drift beyond the Missouri.

The next feature of the section of this basin is the Cretaceous, which system is represented by the Colorado group, consisting of the Pierre, Niobrara and Benton formations. These formations in descending order overlie and overlap the Dakota sandstone. This last named is a widespread deposit ranging from only a few feet to a hundred or more feet in thickness; it is persistent throughout the artesian region, and is the rock furnishing the tremendous flow of the wells.

A short study of this Cretaceous section will indicate the artesian conditions that prevail in this region.

If you start anywhere on the Pre-Cambrian border you will find these formations overlying granite or quartzite. Sometimes as a thin trace—a mere feather edge, as it were, of shale or chalk—but usually appearing in force as one approaches the James river valley. The only surface exposure of the Dakota sandstone is found in the extreme southeastern portion of the state, where it is seen to pass under the Benton shales. These shales and the Niobrara are both found to overlap the Dakota to a greater or less extent. The Benton shales are from 90 to 100 feet thick, and consist largely of "shales and laminated clays with some layers

of very hard limestone all of a lead gray color." Beautiful nests and single crystals of selenite are found in them. Over this formation lies the Niobrara, known locally as "Chalk rock." It contains some "marly clays," and some "thick beds of a light, friable sandstone." It varies in thickness, being at Chamberlain probably about 200 feet.

Above the Niobrara comes the Pierre formation, a heavy deposit of dark, plastic "unctuous clays," with a few fossils, and those appearing in the upper and lower beds. It has a total thickness, according to Dr. Hayden, of 1000 feet, but probably not represented in any one section by more than 350 feet. In all the central and northern portions of the Artesian basin this deposit is passed through in boring the wells. It is absolutely impervious to water, yet when disintegrated it takes up water and forms a tough, sticky mud that makes a "Gumbo" flat the terror of the prairie-dweller.

This is the now fairly well determined section of the Artesian basin.

As one passes up the Missouri river these formations pass under each other with a very slight dip. If one follows this dip through to the head waters of the Missouri river he will find these same formations in outcrop on the slopes of the mountains, with a slight dip eastward and southward along the tributaries of the Missouri watershed. The Dakota sandstone is exposed in thousands of places. Observation and calculation have shown that the visible flow of the Missouri river does not represent by any means the volume of water that is gathered by the Missouri watershed. The position and character of the strata at the headwaters explain its disappearance, and the tremendous volume of over 200 artesian "gushers" shows that both the subterranean flow, and the surface streams have the same source. It is one of the most marked examples of a great river system attested by homogeneous geological conditions that the world furnishes. The inference is that the water beneath will flow as long as the water above, the artesian wells will go dry when the river does, and that will be when snow ceases to melt on the Rocky Mountains.

Now as to the wells themselves:

First, depth.—As I have said the local topography has nothing to do with wells except to modify the depth. The Dakota sandstone lies from 350 to 600 feet above sea level. Ob-

viously wells in the higher localities must go deeper than those in the lower ones. It is found that the sandstone declines toward the north and west rather more than the surface of the country slopes south and west. The Dakota sandstone at Jamestown is 76 feet below sea level, and at Yankton 586 feet above; this shows that the artesian water runs up hill faster than the James river runs down hill. The wells will be found to deepen as you go north from Yankton. At Yankton they average about 628 feet; Woonsocket, 750 feet; Huron, 802 feet; Redfield, 900 feet; Aberdeen, 908 feet; Ellendale, 1,087 feet; Jamestown, 1,487 feet.

The Huron wells probably present as nearly a typical section as can be afforded in the Dakotas. They are all very similar, though, of course, the wells to the south do not penetrate some of the formations that spread over the interior of the two states. Absolute accuracy in description and depth is quite impossible.

The first artesian well sunk at Huron gave the following record:

| | Feet. |
|---|---|
| Glacial drift of the usual composition of this deposit | 89 |
| Bluish gray shale, very tough and becoming sticky when wet, undoubtedly of Pierre formation | 169 |
| Sandstone and gray shale, which may provisionally be referred to the Niobrara | 200 |
| Brown shale, associated with layers of gray marly shale in part; Benton in age | 253 |
| Friable, water-bearing sandstone | 80 |
| Hard pan penetrated only | 10 |
| Total | 802 |

This is about as nearly as I can classify the strata passed through at Huron. Facts are hard to get, and well borers use terms very loosely. I verified this arrangement in other wells, notably at the Day-Harrison well, two miles and a half southwest. Aberdeen corresponds almost exactly, only the Pierre shales are heavier.

Second, the flow in all these wells is marvelous, so great as to awaken scientific incredulity so strong that the facts as first proclaimed were discredited entirely.

The first Huron well (now there are three or four more being sunk) flows 1,560 gallons per minute under a pressure

of 120 pounds per square inch. Woonsocket has three wells, two within 1,800 feet of each other, each flowing 2,370 gallons per minute. A new one, three inches in diameter, one mile away flows 1,000 gallons per minute under a pressure of 120 pounds per square inch. These are a few examples where no less than 150 might be cited. More likely there are over 200 now flowing.

Third, the character of the water is notable. All the wells, with one or two exceptions, yield a clear and bright water. The exceptions are where there are some defects in the piping or where the water comes in contact with the shale at the bottom. In Groton such a condition ruined the well. A new and clear well is now flowing at that place. The water of the wells at Aberdeen has a slightly milky appearance at times, owing probably to a local sediment in the sandstone. Usually the flow is bright and sparkling. The temperature of the water varies from 68° to 70° Fahr., though at Miller and Harold it is 91° and 90°, respectively. In some of the wells the water is soft—as at Iroquois. Everywhere it is palatable and pleasant. Experience has proved it, with only a few exceptions, very healthful. The Jamestown well is an example of one yielding a brackish and saline water. But every well in South Dakota, so far as I am informed, furnishes water that can be used by man and beast.

This opens the question of utility. Its domestic use is already before us and has been sufficiently noted. Its mechanical use is also already established. In many towns and cities it affords the cheapest and best possible fire protection. The problem everywhere is to get hose that will withstand the pressure. Huron uses about 80 pounds pressure per square inch. For power it has been used in a practical way in driving printing presses—no less than three printing houses in Huron are using motors driven by one artesian well.

At Hitchcock a flour mill has been running for two years, driven by a three and one-half inch well—grinding 48 barrels of flour every day. "The natural pressure is so steady and regular that there was absolutely not the variation of a single revolution in 24 hours."

The new six-inch well at Woonsocket is driving a still larger mill by this time. The machinery having been put in place three or four weeks ago.

Lastly and finally, we will consider the use of artesian wells for irrigation. It is more and more becoming an accepted belief that this vast "sub-humid" region must have moisture by other than natural methods, or never be successful as an agricultural country. The rainfall is insufficient and unreliable, showing at Huron, 23.65 inches, at Fort Sully, 16.33 inches per annum. The semi-arid character of the climate appears in various peculiarities of animal and plant life. In this region are two or three species of cactus, such plants as "*Lygodesmia-juncea*," and others with much contracted foliage show what the lack of humidity can accomplish. Then the fauna has shown some dictinctly desert types; the prairie marmot, or dog, is a desert type, and so is the gray plover; the "sand piper," and other birds, are nature's hints as to what the permanent conditions are likely to be.

The soil is everywhere good, from two to four feet of black organic mould occurs, and all it wants is moisture. If the subsoil is saturated well in fall or spring a crop is assured, at least in the wheat bearing belt of the states.

The heavy snowfall of 1881 had this effect; in fact it was felt for four or five seasons. They were years of plenty in the Dakotas. Another effect of irrigation would be the prevention of the hot winds. Artesian water would fill basins that are now dry, and so modify the winds by moisture.

Lake Byron and Lake Preston would be enlarged, and scores and hundreds of these, some greater and others smaller, would be formed. The effect of having these lakes all filled with water and bordered with trees, would be to eliminate practically all danger from the hot winds. It is perfectly feasible to accomplish all these results. There is no longer any doubt about it. The thing has been done, and a yet more extensive application of artesian water will be achieved in the season now approaching.

Two or three scientific bugbears have been effectually disposed of. One is probable lack of water. The water is proved to be there in a practically inexhaustible supply. It has flowed persistently everywhere year after year since 1883. The proximity of new wells has not affected either volume or pressure in any perceptible way. The cost of the wells has been reduced to a reasonable sum. A good well has been put down at Woonsocket for $900. Scores of them will go down this spring at a cost of from $500 to $800. New machinery is now being patented which will

revolutionize artesian well boring. The practical results of all experiments have been perfectly satisfactory. The water does not injure either soil or vegetation. It is used constantly on the lawns about scores of residences, in Huron, Aberdeen, Redfield and Mitchell. It can be applied directly to the crops whenever needed. But ordinary agriculture in Dakota requires simply an overflow of the land in the spring or fall, and with a saturated sub-soil, and the air moistened by a multitude of artificial lakes, the wide fields of South Dakota will wave with wonderful harvests year after year.

The Melville law just in force authorizing the bonding of townships for the purpose of putting down artesian wells is being received with great favor, and will furnish the funds to start the streams of a lasting prosperity in this vigorous young commonwealth

April 7, 1891.

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## SOURCES OF THE CONSTITUENTS OF MINNESOTA SOILS.

*By C. W. Hall.*

CONTENTS.



The soil is the superficial portion of the unconsolidated surface material of the globe; it is the line of contact between the solid portion—the rocks—of the earth's crust and the liquid or