SCIENCE

NEW YORK, JULY 21, 1893.

THE SOUTH DAKOTA ARTESIAN BASIN.

BY W. S. HALL, M.S., M.D., HAVERFORD COLLEGE, HAVERFORD, PA.

THE State of South Dakota is about 320 miles long by 210 miles wide. The Missouri River crosses the middle of the north boundary and flows south-southeast till it reaches the north boundary of Nebraska, when it sweeps around to the east and forms the boundary line between South Dakota and Nebraska. Five great water-courses pass down the long slope of the high plains from the western boundary of the State to the Missouri River. The largest of these is the Cheyenne River, furnishing a drainage channel for the Black Hills, which lie partly in South Dakota and partly in Wyoming. A few small, short streams flow from the east into the Missouri. The James River (formerly called Dakota River) flows in a very direct course, south by east, across the State, bisecting the part of the State east of the Missouri River. The James River valley is a broad plain fron 1,200 feet to 1,300 feet above sea-level. As early as 1882 artesian wells were drilled at different places in the valley with the hope of securing a more abundant supply for the cities and villages which were so rapidly outgrowing their water-supply.

The uniform success in getting water, the abundant supply, the good quality, and the great force with which it was ejected began to attract general attention. It has been demonstrated by numerous and widely-distributed experiments that the whole James River valley is an artesian basin. Geologists and engineers seem to agree that it is the most wonderful artesian basin in the world. The source and limit of the water-supply of this region have been the subject of careful and extended investigations by both Federal and State commissions. In this brief paper the writer will endeavor to give the results of these investigations to date.

1. The source of the supply of water.

There are three general requirements that must be satisfied in seeking for the source of supply of an artesian basin :—

I. The source must be as high as the greatest height to which the water, in any well tapping the basin, will rise.

II. The amount of rainfall on the source-area must be adequate to account for the supply of the basin.

III. The geological formations between the source and the basin must be such as to allow the passage of the water through a pervious stratum between two impervious strata.

Several theories exist as to the source of the supply in the basin in question : (*a*) The Great Lakes ; (*b*) the Canadian lakes; (*c*) Devil's Lake, North Dakota; (*d*) the Missouri River; (*e*) the elevated region west of the Missouri River, including the foot-hills and the east slope of the Rocky Mountains.

Let us apply the three requirements stated above to the regions just named.

The height to which the water of the Redfield, South Dakota, well would rise, if the tube were extended, is 1,700 feet A. T.[1] There are other wells north and west of Redfield whose water would rise to a greater height.[1] The well at Highmore has a flow of nine gallons and a pressure of twelve pounds at an altitude of 1,890 feet.[2] But the altitude of the Great Lakes and of the Canadian lakes is many hundred feet below that height.[3] The altitude of Devil's Lake is about 1,440 feet,[1] and the altitude of the Missouri River where it enters South Dakota is not over 1,500 feet.[3]

[1] "Artesian and Underflow Investigation," Part II., Col. E. S. Nettleton, Chief Engineer. Appendices XVIII., XIX., and XX.

[2] "Artesian and Underground Investigation," Part IV., F. B. Coffin, Engineer for South Dakota.

[3] American Geological Railroad Guide. Macfarlane.

It therefore follows that neither the Great Lakes, the Canadian lakes, nor Devil's Lake can be the source. Nor can the Missouri River within the State be the source. We are now confined to our last alternative,—the elevated region west of the Missouri River,—which may, for convenience, be considered under two heads: (1) The High Plains, and (2) The Foot-Hills of the Rockies. (1) The high plains attain an altitude of 1,900 feet about 50 miles west of the Missouri River.[4] They satisfy requirement I.

An idea of the water-supply of an artesian basin can be gotten only by finding the amount of water that can be drawn off without lessening the flow and pressure of individual wells. W. P. Butler, engineer of Aberdeen, South Dakota, under date of June, 1892, says that "two hundred wells have already been put down in North and South Dakota."[5] The same engineer gives a "Table of twenty-four South Dakota wells showing flow in gallons per minute."[6] The range of discharge, as shown by this table, is from 150 gallons to 7,000 gallons per minute; the intermediate points seem to be sufficiently represented to indicate that the table is fairly representative. Taking this table as a basis, the average flow of a South Dakota artesian well is 1,655 gallons per minute. Two hundred wells would, at that rate, discharge 685 million tons per annum. No diminution in the pressure of any of the wells has been detected. The limit has, therefore, not yet been approached. Now many times the amount annually discharged by the South Dakota artesian wells falls each year upon the high plains (region *e*, 1) west of the Missouri River in South Dakota; but the rapid evaporation from the surface, the ready drainage into the Missouri River, and the impervious shales beneath the surface preclude the possibility of the high-plain rainfall taking any appreciable part in the water-supply of the basin. Driven now to our last alternative, let us apply our three tests in succession.

I. The elevation of the foot-hills varies from 3,000 feet to 8,000 feet above sea-level, which is certainly sufficient altitude above the James River valley to overcome the resistance and give the wells a high pressure 240 to 600 miles away.

II. The annual rainfall in the foot-hills is greater per given area than on the high plains.[7]

The area of the foot-hills, whose rainfall can get access to the water-bearing rocks, is not far from 40,000 square miles, upon which area not less than 69,600 million tons of water fall per annum, which is one hundred times as much as that drawn annually from the artesian basin of the Dakotas.

III. The geological formation between the Black Hills and the James River valley is well shown by the accompanying figure.[8]

A glance at this figure will show that water entering the porous Dakota sandstone above Rapid City will produce the conditions for an artesian flow in the region of the James River and the Missouri River. The lower altitude of the former will make the flow stronger there, even though it be farther away from the source. The increasing altitude as one goes west from the Missouri River will undoubtedly decrease or wholly prevent a flow. Any geological section taken across the Dakotas from east to west would be similar to the one shown. Wherever the section would pass through foot-hills or mountain ranges the upturned edges of the absorbing strata would crop out.

The three requirements being satisfied by the last region tested, it has been demonstrated beyond a shadow of doubt that the source of the water-supply of the James River artesian basin is

[4] "Artesian and Underflow Investigation," Part IV., F. B. Coffin.

[5] Irrigation Manual. W. P. B. p. 9.

[6] Irrigation Manual. W. P. B. p. 38.

[7] Irrigation Manual, W. P. Butler, p. 94, "On the high plain the rainfall is 15 to 20 inches, while in the Black Hills it is 20 to 30 inches per annum."

[8] "Irrigation and Underflow Investigation," Part III., Special Report by Professor G. E. Culver, State Geologist.

the elevated, well-watered hills and low mountains, together with the east slope of the Rockies in South Dakota, Montana, and Wyoming.

2. The limitations of the supply.

It was estimated that about 69,600 million tons of water fall annually on the foot-hills within this drainage basin. Having limited the source to the foot-hills, it is clear that the limitations can be carried further. The water flowing through the Dakota sandstone must either (*a*) have fallen directly upon the area of outcrop, or (*b*) have sunk into it from streams flowing over it, or (*c*) have escaped into it at high altitudes from other strata.

(*a*) It is estimated by Professor G. E. Culver[1] that about $\frac{1}{72}$ of the rainfall of the Black Hills falls directly upon the outcropping Dakota sandstone. If this outcrop forms the same proportion of other foot-hills, then about 966 million tons per annum would fall directly upon this; and, as it is estimated that one-third of the rain-fall is absorbed by the soil, 322 million tons would be poured directly into the artesian basin.

(*b*) As far as the writer knows, but one stream has been carefully studied as to the quantity of water lost to the stratum in question. Below Great Falls, Montana, the Missouri River flows across the outcropping Dakota sandstone at an altitude of 2,800 feet. Col. E. S. Nettleton[2] made careful gaugings of the river before and after crossing the sandstone and found that it lost "834 cubic feet per second," which would amount to 918 million tons per annum. The Yellowstone River, which is about as large as the Missouri above their confluence, is said to flow across the Dakota sandstone and to lose a part of its volume. It is generally true that all streams flowing out of the foot-hills or away from the Rockies must, somewhere in their eastward course, cross the absorbing stratum. To estimate three times 918 million tons as the amount received from source (*b*) will probably fall much within the limits. That gives us an aggregate from (*a*) and (*b*) of 3,076 million tons per annum.

(*c*) The outcrop of the Carboniferous forms a much larger part of the foot-hills area than does the Dakota. At least one-third of the water which falls directly upon it sinks, while nearly all of the small streams flowing out of the central Archæan area of the hills sink completely into the Carboniferous, only a few of the largest streams emerge from the thirsty Carboniferous area. The amount of water entering the Carboniferous strata is many times greater than that entering the Dakota. Now it is possible for nearly all of the water which it absorbs to escape into the Dakota, which it would do anywhere between its source and the James River valley if either one of two things were true: (1) If the overlying stratum "pinches out," or (2) if it is fractured or faulted. Both, one, or neither of these things may be true. No one has yet attempted to answer, conclusively, the question, "What becomes of the water which sinks into the Carboniferous limestone of the hills?" Until that question is answered, it will be impossible to determine the limitations of the water-supply of the artesian basin.

[1] "Artesian and Underflow Investigation," Part III., p. 207.

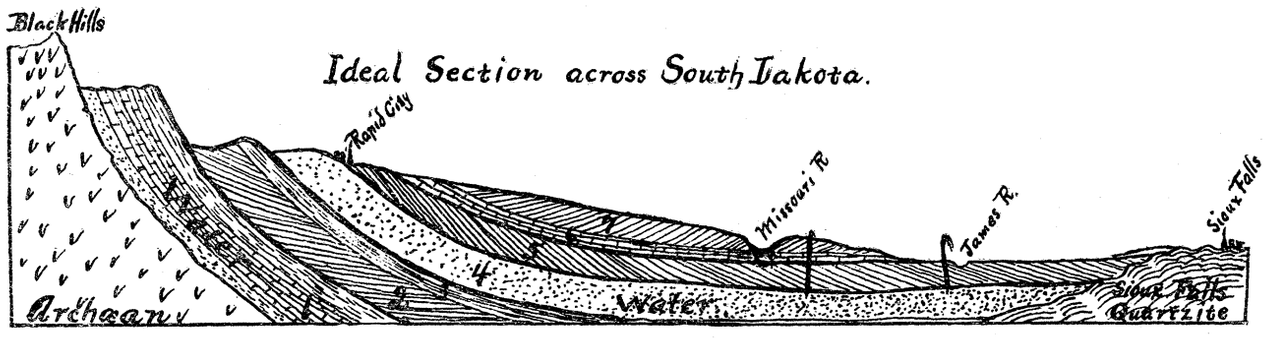
[2] "Artesian and Underflow Investigation," Part II., p. 77.

A ROW OF HIEROGLYPHS, CASA NO. 2, PALENQUE.

BY H. T. CRESSON, A.M., M.D., PHILADELPHIA, PA.

THERE is a perpendicular row of three glyphs just above the child-like figure, upheld in the arms of the *Ahkin* (?), on the centre slab of the so-called "Group of the Cross," Casa No. 2, (Stephens), Palenque, and two hieroglyphs in the parallel line to the right of the perpendicular line just mentioned, which are exceedingly interesting, and all of them, except the upper-centre component of the glyph, just above the child-like figure, are in a fair state of preservation. The upper centre component of this glyph (Fig. 6) has been badly injured, if we may judge by a photograph of the slab from Casa No. 2, taken by Dr. Manuel Urbino, the learned conservator of the Muséo Nacional, at the City of Mexico It is a lucky circumstance that this masterpiece of the Maya scribe-sculptor's art has been cared for by the Mexican government, and it is to be hoped that they will protect other tablets at Palenque from the wanton destruction of the Mayas, who have been accused, by recent explorers, of chopping to pieces, with their *machetes*, the artistic productions of their ancestors.

It will be impossible, in this necessarily brief article, to consider the entire row of glyphs which have been indicated, we will, therefore, confine our remarks to that shown in Fig. 6 of the plate. If we compare this sketch, made from a photograph of the middle slab of the cross group (Casa No. 2, Palenque), taken by Dr. Urbino, it will be seen that it differs in certain respects from the drawing of Del Rio, Waldeck, Catherwood, and Charnay. Del Rio's rendition of this hieroglyph (Fig. 1) is absurdly incorrect, and has been suggested, we think, either by a slovenly impression of the centre bar of a cross (see Waldeck's Fig. 2), or else the artist drew upon his imagination and supplied the detail.



Length of Section, 385 miles. Rapid City to James River Valley, 230 miles.

1, Paleozoic rocks, mostly water-bearing Carboniferous limestone; 2, Triassic shales, impervious; 3, Jurassic shales, impervious; 4, Cretaceous, Dakota sandstone, water-bearing; 5, Cretaceous, Benton shales, impervious; 6, Cretaceous, Niobrara limestone; 7, Cretaceous, Pierre shales, impervious.

Waldeck's drawing (Fig. 2) in four of the small glyphs (composing the compound glyph) is not so far astray as one might expect, judging by the way his drawings have been condemned by some writers, and I find that in the perpendicular and the parallel row of glyphs of the Casa No. 2 tablet, to the right of the symbol of the days, four winds, and cardinal points (called by many the Cross), his work compares quite as well with the photograph as that of Charnay, who used the camera, and Catherwood, who used the camera lucida. So far as I can learn, Mr. Waldeck used no artificial aids to assist him in his work (?); if this be the case, his eye must have been an unusually correct one, considering the amount of work he accomplished, and the confusing details that he encountered, to say nothing of annoyances in the way of flies, mosquitoes, garapatas, and other insects. I think the truth of this assertion will be apparent to anyone who has attempted to make a careful drawing under difficulties of this kind, especially such intricate details as we find in ancient Maya architecture and hieroglyphs, well calculated to give an experienced draftsman the headache and heartache. The centre-upper component of the hieroglyph, drawn by Waldeck, differs from that of Fig. 6, but I must not neglect to mention that the Urbino photograph indicates that this component of the glyph has been so injured that it is difficult, at present, to determine the details. The round incisions