# DESCRIPTION OF THE PARKER QUADRANGLE.

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## GEOGRAPHY.

### GENERAL RELATIONS.

Eastern South Dakota lies on the Great Plains, in the broad, indefinite zone in which these plains merge into the prairies of the Mississippi Valley. It is comprised within the area of glaciation, and most of its surface features show the characteristics of a drift-covered region. The country is generally level or presents rolling slopes rising out of broad expanses of plains. The principal elements of relief are long ridges of morainal accumulations left by the ice, marking various stages of glacial equilibrium, advance, and retreat. Further diversity of topography has been produced by the excavation of the valleys, especially that of the Missouri, which has cut a trench several hundred feet deep, mostly with steeply sloping sides. Between the moraines there are rolling plains of till and very level plains due to the filling of glacial lakes. The middle James River Valley presents a notable example of this lake-bed topography.

### LOCATION.

The Parker quadrangle is located between longitudes 97° and 97° 30′ west and between latitudes 43° and 43° 30′ north, and comprises about 871 square miles. It lies chiefly in Turner County, but includes also portions of Hutchinson, Yankton, and Clay counties, S. Dak. It occupies portions of the valleys of James and Vermilion rivers and Clay Creek, all of which flow southward into Missouri River. It is almost wholly a prairie region, only a few groves occurring near the principal streams.

### TOPOGRAPHY.

The surface of the quadrangle is sufficiently level for agricultural purposes, except along the bluffs adjoining the streams and on the steeper slopes of the higher hills. It varies in altitude between 1175 feet, along the bottom lands of James and Vermilion rivers, and 1750 feet, at the culmination of Turkey Ridge in sec. 5, T. 97, R. 55. Much of the surface lies at an elevation of about 1350 feet, but the average height is not far from 1450 feet.

The surface presents striking contrasts. The area in the northwest corner of the quadrangle, covering about 40 square miles, is very even and flat. The same may be said of much of the James River Valley, in the southwest corner, and of about 25 square miles along the Vermilion Valley east of Hurley. In these areas elevations more than 5 feet above the general surface are rarely found. On the other hand, the elevated region known as Turkey Ridge bears numerous stony knobs on its top. This ridge is 5 or 6 miles wide and has moderately steep slopes (in some places 200 feet to the mile), which are deeply cut by ravines. Moreover, the streams that drain it, especially toward the south, have cut canyons to a depth of 200 to 300 feet, and have deep tributary ravines. Similar rough areas are found also in the extreme southwest corner and in the extreme northeast corner of the quadrangle.

In the southwest corner of T. 95, R. 56, lies James Ridge, an elevated, even-topped divide, a little more than a mile wide, rising abruptly to a height of nearly 200 feet above the surrounding country. It is of morainic origin, and is cut through by Beaver Creek. Its highest point, near the western border of the quadrangle, is 1560 feet above sea level. Southwest of James Ridge is a small portion of the valley of Beaver Creek, which merges into a broad plain toward the west.

Turkey Ridge is an extensive elevated divide situated wholly within the quadrangle, its axis lying northwest and southeast. Including its lower slopes, it has a width of from 10 to 12 miles and a length of about 23 miles. Its summit is a rough plain which slopes southeastward from an altitude of 1750 feet to about 1450 feet. Toward the north its slopes are abrupt, especially on the east side. Its southeastern third is composed largely of chalk and has been cut by the deep, canyon-like valleys of Clay Creek and Turkey Creek, which join a mile south of the southern boundary of the quadrangle. In one respect Turkey Ridge resembles the Choteau Creek Hills. The northwestern end of the principal portion, which has been described, is encircled by a high, continuous morainic ridge that is separated from it by the upper portions of the valleys of Clay and Turkey Ridge creeks. This encircling ridge is narrow, but nearly continuous, being broken at only a few points by shallow cols. About 2 miles south of Freeman it rises to an altitude of about 1650 feet, and very gradually declines in height toward the northeast and the south. Northeastward it continues in a low, broad swell, not sinking much below 1450 feet, across the West Fork of Vermilion River, and joins the divide between that stream and the East Fork.

Within the quadrangle are also included 4 or 5 square miles of the abrupt western slope of the high table land east of the Vermilion River Valley, frequently spoken of as the East Coteau. Its longer name, applied by Nicollet and probably derived from the early French voyagers, is Plateau du Coteau des Prairies, and its highest altitude within the quadrangle is about 1550 feet, which is considerably lower than points a mile or two farther northeast.

The James River Basin includes two extensive areas in the quadrangle. The southern one, which lies along James River, has a width of 7 or 8 miles from northeast to southwest. Its surface lies about 100 feet above the flood plain of that stream. It is rather even and nearly level. Near the southern boundary it is broken by a morainic ridge of small extent, rising about 100 feet above the general surface. The trough of the river is cut in the bottom of this basin and has a depth of 100 feet and an average width of half a mile. The slopes forming the sides of the trough are abrupt and are strewn with bowlders. The other area in the quadrangle that drains into James River occupies one or two townships in the northwest corner. It includes the plain already mentioned and a very gradual slope from it toward the southeast to the ridge which encircles the northwest end of Turkey Ridge. Eastward the plain merges imperceptibly into the valley of the East Fork of the Vermilion.

The valley of the latter stream rises gently on the west about 100 feet to the summit of the divide between the West and East forks. The West Fork, beginning apparently in the James River Basin, passes through the morainal ridge by a narrow gap, nearly 200 feet in depth, situated halfway between Marion and Parker.

Of the Vermilion Valley, there is within the quadrangle a small portion along the East Fork, which has an altitude of about 1350 feet and a width of 3 or 4 miles, with ill-defined sides. This valley rises gradually on the west to the divide already mentioned and on the northeast to the foot of the East Coteau. South of its junction with the West Fork, the Vermilion Valley widens into a sandy plain, poorly drained, and having a width northeast of Hurley of about 5 miles. It preserves the same general character to the vicinity of Hooker, though it becomes much narrower.

West of this plain is a second plain, less clearly defined, that lies somewhat higher. It includes the shallow valleys of the several tributaries of the Vermilion coming from the east slope of Turkey Ridge, with low, swell-like divides between them. The general course of these valleys is southeastward. The principal one is that of Turkey Ridge Creek, whose headwaters have already been mentioned. Next is a valley passing west of Viborg, not occupied by a distinct stream; and next in order is the generally rather uneven valley of Frog Creek, also an intermittent stream. The trough of Frog Creek is bounded by bluffs, usually not more than 50 feet high, and in some places much less than that.

## GENERAL GEOLOGY.

The surface of eastern South Dakota is in large part covered with a mantle of glacial deposits consisting of gravel, sand, silt, and clay of varying thickness, which is described under the heading "Pleistocene deposits."

The formations underlying eastern South Dakota are seldom exposed east of Missouri River, although they outcrop in some of the hills where the drift is thin and in the banks of a few of the streams. The numerous deep wells throughout the region have, however, afforded much information as to the underground structure. There are extensive sheets of clays and sandstones of Cretaceous age lying on an irregular floor of granite and quartzite of Archean and Algonkian age. Under most of the region this floor of older rocks lies more than a thousand feet deep, but it gradually rises to the surface in the northeastern portion of the State. There is also an underground quartzite ridge, of considerable prominence, that extends southwestward from outcrops in southwestern Minnesota to the vicinity of Mitchell, S. Dak.

The lowest sedimentary formation lying on this old rock floor beneath the greater part of the area is a succession of sandstones and shales termed the Dakota formation, which furnishes large volumes of water to thousands of wells. It reaches a thickness of 300 feet or more in portions of the region, but thins out and does not continue over the underground quartzite ridge above referred to. It is overlain by a few hundred feet of Benton shales, with thin sandstone and limestone layers, and by a widely extended sheet of Niobrara formation consisting largely of chalkstone toward the south and merging into limy clays northward. Where these formations appear at the surface they rise in an anticlinal arch of considerable prominence along the underground ridge above mentioned, but they dip away to the north and west and lie several hundred feet deep in the north-central portion of the State. In the Missouri Valley they rise gradually to the southeast and reach the surface in succession, the Dakota sandstone finally outcropping in the vicinity of Sioux City and southward. The Pierre shale extends in a thick mantle into eastern South Dakota, lying under the drift in the greater portion of the region, except in the vicinity of the higher portions of the anticlinal uplift above referred to. It was no doubt once continuous over the entire area, but was extensively removed by erosion prior to the Glacial epoch. Doubtless the Fox Hills and Laramie formations once extended some distance east of Missouri River, but they also have undergone widespread erosion and but few traces of them now remain in the extreme northern portion of the State. Tertiary deposits appear to have been laid down over part of the region, as shown by small remnants still remaining in the Bijou Hills and other high ridges.

Within the Parker quadrangle the drift, as already noted, covers the entire surface except the alluvial flats in the larger valleys and scattered exposures of older rocks that occur mainly along the sides of the canyons in the southern part of Turkey Ridge and on the bottoms of the river channels in the northeast corner of the area. The strata lie nearly horizontal everywhere. No folds, faults, or igneous outflows have been discovered within the quadrangle. Frequent borings have been made to a depth of 200 or 300 feet for wells, and a few have been sunk to 600 or 700. These have furnished important facts concerning the position of the strata below the surface.

### ALGONKIAN SYSTEM.

*Sioux quartzite.*—The oldest rocks exposed in the quadrangle or encountered in borings belong to the Sioux quartzite. This is for the most part a red or purplish quartzite, intensely compact and durable. It lies in strata which in this quadrangle dip generally to the north at an angle of 3 to 5 degrees. No trace has been found of slate or pipestone in any of the exposures of this formation, and no fossils have been observed.

The quartzite occurs at a number of points along the East Vermilion, from the north line of the quadrangle to the vicinity of Parker. These exposures are represented on the Areal Geology sheet. In sec. 8, T. 100, R. 53, the quartzite is in layers generally not more than 6 inches thick. East of Parker it is more massive and the layers are 2 or 3 feet thick. Borings some distance from these exposures have reached this formation, and the general configuration of its surface is indicated by contours on the Artesian Water sheet. The rock is frequently called the "Sioux Falls granite" from its extensive exposure in the vicinity of Sioux Falls, where it is extensively quarried. Its thickness has not been determined. At Sioux Falls a boring 500 feet deep revealed no important differences in the character of the rock.

### CRETACEOUS SYSTEM.

Eastern South Dakota is underlain by several formations of Cretaceous age, including the Dakota, Benton, Niobrara, and Pierre. Of these only the Niobrara formation is certainly exposed at the surface in this quadrangle, though the Benton and Dakota are often recognized in well records. One outcrop of dark clay in Turkey Ridge may be the Pierre shale. It is possible that the Lakota sandstone and Fuson shale of the Lower Cretaceous occur in association with the Dakota of this area, but they have not so far been discriminated in the well records. The beds known to occur belong entirely to the Upper Cretaceous. Figs. 1 to 5 illustrate the composition of these formations in the quadrangle as observed in certain wells.

### DAKOTA FORMATION.

Resting on the quartzite in the southwestern portion of the quadrangle, as shown by many borings, is a series of sandstones and shales, which Dr.

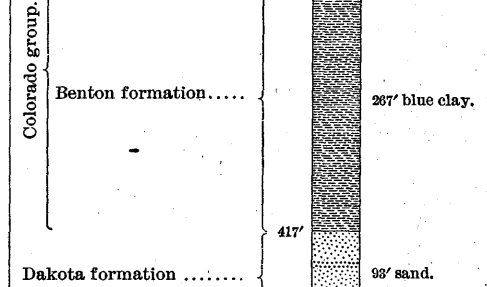


FIG. 1.—Section of well 5 miles west of Hurley.

F. V. Hayden named the Dakota formation, from its extensive outcrops near Dakota City, Nebr.

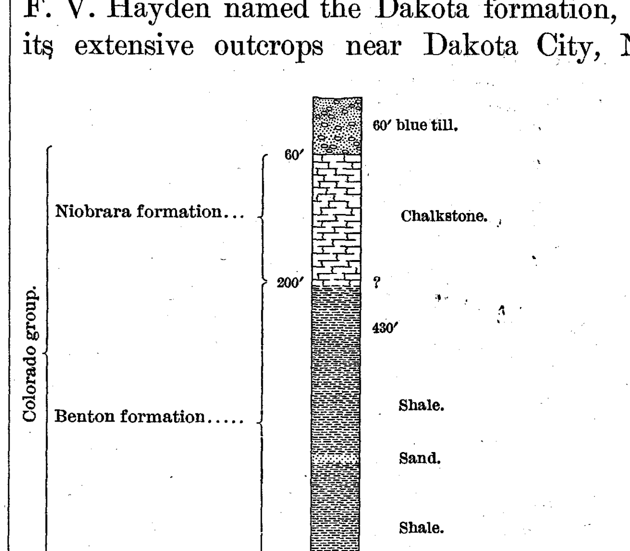


FIG. 2.—Section of well 3 miles southwest of Mayfield.

This formation is not exposed in this quadrangle, but its presence is established in many borings, to which it supplies an abundance of water. By means of these well data, the formation is known to underlie the central and southern portions of the quadrangle, thinning out gradually to the north and northeast. As the surface of the quartzite is uneven the outer margin of Dakota deposits undoubtedly is irregular. In the southern part of the quadrangle the Dakota sandstone probably has a thickness of 200 or 300 feet, but as deep borings in that region are few and as none are positively known to have passed through the formation, this thickness is only an estimate. From exposures elsewhere and from borings in this quadrangle it is known that the formation is composed of sheets of sand or sandstone more or less

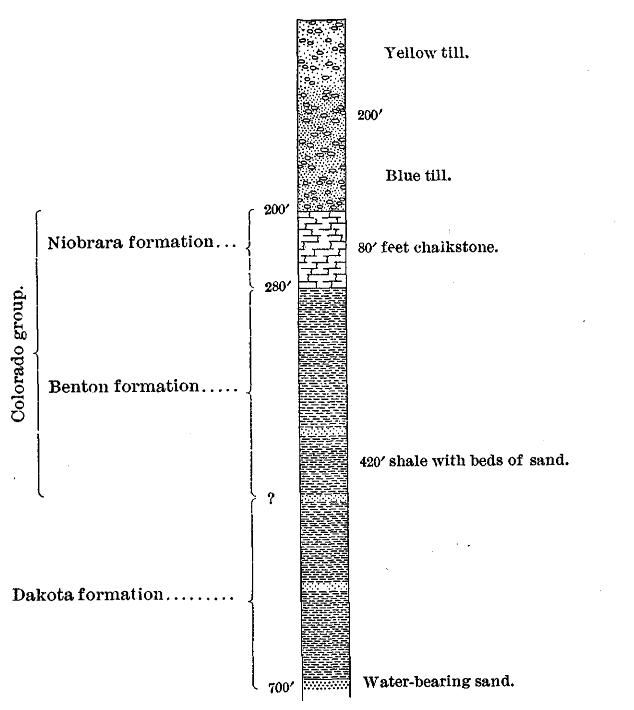


FIG. 3.—Section of well on Mud Creek, 4 miles northwest of Hanson.

completely separated by beds of clay and shale. The sandstone strata are usually of fine-grained, well-washed material, and vary in thickness from 10 to 150 feet. The clay deposits often are thick and vary from soft, plastic clay to hard shale. The number of water-bearing sandstone strata in the Dakota increases toward the south as the formation thickens. Three fairly well-defined horizons are

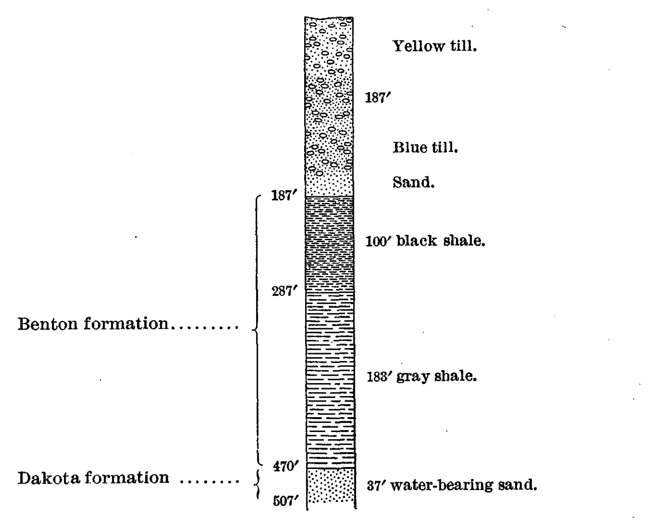


FIG. 4.—Section of well 6 miles northeast of Wakonda.

found in the James River Valley near the south line of the quadrangle. In eastern South Dakota the upper part of the sandstone stratum usually presents harder layers, which are often spoken of as the "cap rock." They are sometimes so hard as to give the impression that the red quartzite has been struck, but in all cases, so far as known, the cement is calcareous or ferruginous rather than

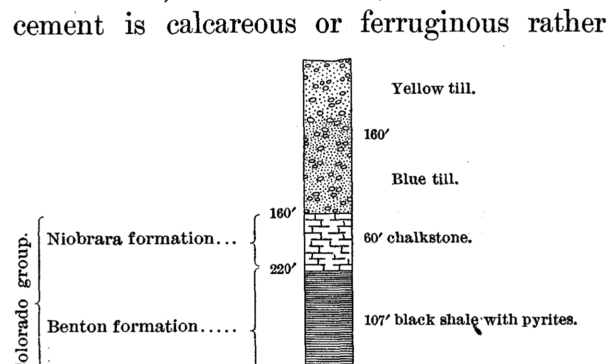


FIG. 5.—Section of well 6 miles north of Freeman.

siliceous, as in the quartzite. The calcareous character is easily revealed by use of an acid which causes effervesence, and ferruginous cement is easily shown by its dark color.

The surface of the Dakota sandstone rises toward the area of quartzite exposure, and also slightly toward the east. The formation is overlapped to the north and still more to the east by the formations of the Colorado group, as is shown on the cross section, fig. 7.

### COLORADO GROUP.

This group includes two formations, which were first separated by Dr. F. V. Hayden. The lower is composed mostly of shale and clay, with occasional layers and concretions of limestone and layers of sandstone. It was named Benton from its typical development near Fort Benton, Mont. The upper series, which is composed largely of chalkstone, Dr. Hayden named the Niobrara, from its development along the Missouri near the mouth of the Niobrara and some distance up that stream. The distinctions most easily recognized are lithologic, as already given.

*Benton formation.*—This formation is known in this quadrangle only in well records, and in these its limits are not always clearly defined from the Niobrara. As determined from exposures and borings elsewhere, it consists of shale and plastic clay abounding in iron pyrites which oxidizes when exposed to the air. The products of this oxidation and the resulting reaction on lime compounds in the shale are numerous selenite crystals and small veins of gypsum and sometimes other more soluble sulphates. The Benton includes also thin beds of sandstone, from which water is obtained in a large portion of the quadrangle, but which does not usually produce flowing wells. The plastic clay is frequently pure enough to be valuable for the manufacture of pottery and brick.

*Niobrara formation.*—The Niobrara is finely exposed in the southern portion of Turkey Ridge. As shown on the geologic map, there are numerous exposures, some of them nearly 100 feet high, along the valley of Clay Creek and Turkey Ridge Creek, but a complete section of the formation is not presented in any one locality. It is prevalently a gray chalk, which weathers white or light yellow. It is not very homogeneous because of the presence of clay material. Some layers afford nearly pure chalk. It contains the usual fossils found in this formation throughout the western part of the Missouri Valley from Kansas to North Dakota. A small oyster, *Ostrea congesta*, abounds in portions of some harder layers. This is usually found attached to the broken valves of large *Inoceramus* and *Pinna* shells. Certain layers are very rich in the scales of teleost fishes, and in the teeth both of such fishes and of sharks. Occasionally, thin layers are found composed almost entirely of fish teeth and fish bones. The chalk rarely shows complete shells of Foraminifera of the species characteristic of this formation. It shows, however, their comminuted fragments mingled with coccoliths and other organisms that are usually associated with them. The chalk has had an important effect on the topography of the region. The streams of the Glacial epoch rapidly cut through it, leaving the formation standing with abrupt slopes, so that, in this southern part of the quadrangle, several narrow gorges occur, which are unusual in glaciated regions.

### PIERRE SHALE.

The Pierre shale overlies the Niobrara, and it is very thickly developed along Missouri River in the central portion of the State. That a considerable portion of it still rests on the Niobrara chalk in the higher portions of Turkey Ridge is indicated not only by a few rather indecisive records of borings, but also by an exposure in the southwest corner of sec. 15, T. 96, R. 54, where the following section was measured:

*Section in sec. 15, T. 96, R. 54.*

| | | Feet. |
|---|---|---|
| 6. | Yellow, sandy drift clay .............. | 3–5 |
| 5. | Light cream-colored loam.............. | 5–6 |
| 4. | Dark lead-colored laminated clay, reddish above........................ | 5–6 |
| 3. | Slope of whitish clay.................... | 4–5 |
| 2. | A cliff of chalk irregularly stratified .... | 70 |
| 1. | Slope to level of creek.................. | 10 |

No. 4 resembles the Pierre shale and may be regarded as the lower portion of that formation, although it contains no fossils to demonstrate the fact. This exposure begins at an altitude of about 1425 feet. It seems probable that at least 50 feet or more of the Pierre may be found extending very generally under the drift in Turkey Ridge northwest of this outcrop.

### TERTIARY DEPOSITS.

Of the formations of Tertiary age we have no representatives except possibly of the late Neocene (Pliocene). The light-colored loam, No. 5 of the section just given, may possibly belong to that age. A similar deposit is found about a mile east of this exposure, and from a comparison of well borings it seems to have been struck at some other elevated points. It seems to be a land formation—probably hillside wash or eolian deposit—although it may be the deposit of some gently flowing stream or lake. It resembles in its general texture the loess, but differs from it in color and seems on the whole to be more sandy. Part of the deep sands on Turkey Ridge below the drift may be Pliocene.

### PLEISTOCENE DEPOSITS.

*Extent and classification of deposits.*—In the Parker quadrangle, as in the surrounding region, the Pleistocene deposits form the most conspicuous geologic feature. Glacial drift covers practically the whole surface. Even where the chalk forms most of the slope the drift has been washed down over it and largely conceals its presence. The deposits of the Glacial epoch in this region may be enumerated in chronological order as follows: (1) Circumglacial sands and gravel; (2) bowlder clay or till, separable into the yellow or upper bowlder clay and the blue or lower bowlder clay; (3) moraines, which include those of two distinct epochs, with minor subdivisions; (4) terraces and ancient channels, which may be referred to three or four different stages of the glacial occupation of the country; and (5) alluvium.

*Circumglacial deposits.*—The pre-Glacial surface was probably covered with silt and clays resembling those found in the region west of Missouri River. The surface there, however, is probably now eroding faster than when these were deposited, for the base-levels of drainage channels were relatively much higher at that time; consequently the valleys were probably much broader and of gentler grade. The hillside wash and alluvium were doubtless more conspicuous than they are now in the trans-Missouri region, but as the ice sheet, resembling that of Greenland at the present time, slowly advanced from the north, there was spread before it almost everywhere an apron or fringe of torrential deposits. Heavy sand and gravel bars were formed along the channels of the principal streams leading from the ice sheet. Similar deposits in smaller amount accumulated in all watercourses as their upper portions began to be supplied from the melting ice. Hence most of the surface was covered with a nearly continuous layer of sand and gravel, and as the result of the process we find to-day nearly everywhere below the till of this region a stratum of sand and gravel containing, in most cases, abundant water. The finer portions of pre-Glacial soil and surficial deposits of that time seem to have been washed away, leaving the sand clean and porous. This deposit of sand, which may be compared to a blanket, lies over the uneven surface of the Cretaceous clays, mantling the upland as well as the lowland. It is generally thicker on the higher points, where its accumulation may be due in part to the action of winds. It is needless, perhaps, to remark that the sands of this deposit, like the bowlder clay above, contain pebbles of granite, greenstone, and limestone. This sand is rarely exposed, but it appears at a few places along the base of the bluffs of the larger streams. It may be recognized sometimes by the occurrence of springs near the level of the streams. It appears, usually with less thickness, above the older rocks wherever they are exposed. At these places, however, it is not so often the source of springs, because such points are more elevated and because the bowlder clay has crept down and covered it more frequently than where it has been more recently exposed by the action of the stream. In some places this deposit attains a thickness ot 100 feet, but usually it is very much thinner. It is entirely absent in some places, so that the well borer passes from the bowlder clay into the Cretaceous clay without finding an intervening stratum. This formation plays an important part in the water supply of the region, and will be further described under that head.

*Till or bowlder clay.*—The till presents the same features that are found in corresponding regions elsewhere, as in central Minnesota, Iowa, and Illinois. It is an unstratified mixture of clay, sand, and worn pebbles and bowlders, the last mentioned sometimes attaining a diameter of several feet. In this formation are found local deposits of stratified sand, commonly spoken of as "pockets," though they are sometimes known to be portions of channels of considerable length, and also of sheets that may locally separate the bowlder clay into two or more members. In this region the till is much more clayey than it is at points farther east, because here for some distance the ice moved over and deeply eroded dark-colored Cretaceous clays. For this reason the erratics are perhaps less frequently striated and planed. The bowlders most widely distributed are gray and reddish granites, and peculiarly compact and fine-grained limestones of a straw color or clear white. The latter contain *Favosites* and cup-corals with occasional brachiopods, indicating their Paleozoic origin. Next in prominence are bowlders of a fine-grained trap or greenstone. Besides these, in some portions, a large percentage of the erratics, though usually of smaller size, are from the red quartzite. The distribution of these will be further mentioned in connection with the moraines.

The till varies in thickness at different localities, ranging from 30 feet to 300. It is generally thicker on high elevations, like Turkey Ridge and James Ridge. Near the exposures of older rocks, which we may suppose are points that have most resisted pre-Glacial erosion, we find a thickness of from 80 to 100 feet, as over the red quartzite in the northeast corner of the quadrangle, and the chalkstone along Turkey Ridge and Clay creeks. On the plain northwest of Turkey Ridge a thickness of from 200 to 250 feet is common. On the higher elevations nearer the end of Turkey Ridge 150 feet of till is found, with 50 to 100 feet of sand, probably of glacial origin, beneath. As the pre-Glacial surface was very uneven, especially in Turkey Ridge, there are considerable variations in thickness of the till within short distances. In well drilling the surest evidence that the bottom of the till has been reached is the fact that water, when struck, rises immediately to a considerable height.

The chalk from its nature tends to produce a more uneven surface than the Benton or Pierre, or even, perhaps, the quartzite. There seems to have been a low escarpment of chalk extending along the valley northeast of Turkey Ridge. This is attested by the frequent occurrence of flowing wells of rather shallow depth. In general, the water seems to come from the chalk, and the bottom of the till is, therefore, clearly marked. The till is about 40 feet thick along the east side of T. 95, R. 53, and along the west side of the shallow artesian basin crossing the northeast corner of T. 97, R. 54. The same relation shows also in the vicinity of Hurley. A further discussion of these wells and the geologic features is presented below.

It has been noted in other regions that the till consists of two or more members belonging to different epochs, and it would seem not improbable that this may be the case in this quadrangle, but so far no direct evidence of any drift older than the main sheet, which is of Wisconsin age, has been found. There is, however, a suggestion of a slight difference in the age of different portions of this sheet. In the lower part of the James River Valley, between Clay Creek and Beaver Creek, the till corresponding to the advance of the ice that occupied the second (Gary) moraine is found to overlie thick deposits of sand and gravel, which doubtless rest upon the older till formed during the occupation of the first (Altamont) moraine.

This has not been proved by direct observation. In the bluffs of James River at the southern boundary of this quadrangle deep deposits of drift, sand, and gravel are found underlying the upper till. The lower till has not been clearly recognized, but from the depth which it is necessary to go for water in wells there is very little doubt that the till occurs in considerable thickness below the gravel. The distance which this intercalated sheet of sand extends up the valley of James River has not yet been determined.

The upper part of the till weathers to a light-buff or yellowish color, and it is only at unusually recent natural exposures, or in deep wells, that the blue unweathered till appears. An impression prevails that the latter differs materially in character from the yellow till, for the yellow till contains water, often in considerable quantity, which supplies the shallow or surface wells of the country. A general rule is that if sufficient water is not struck before the blue clay is reached no more can be expected until that formation is completely penetrated. The blue till is frequently spoken of as joint clay from the fact that it is usually divided into polygonal masses by irregular joints crossing one another. These joints allow slight motion wherever the formation lies upon a slope, so that in the vicinity of streams, though it is less plastic than the Cretaceous clays, it is subject to landslides which cause it to cover up the underlying sands.

The surface of the till in this quadrangle, as elsewhere in this region, abounds in shallow basins or lake beds, which, in the wet season, may be filled with water. In some localities these are so deep that they retain water several feet in depth year after year, but more frequently they are dried up by the advancing summer and are capable of tillage. Since none of them are supplied except by rainfall, even the deepest are likely to become empty after a succession of dry years.

*Moraines.*—These are local developments of the till in the form of elevated ridges, usually with a rougher surface than the surrounding country. The intervening depressions and basins are also more marked than are the depressions elsewhere. The ridges or knolls are often abrupt, rising perhaps to the height of 25 or 30 feet, and separating land-locked basins. Moreover, on the moraines bowlders and beds of gravel are usually more plentiful than on the drift plains and there are other marks of abundant and free-flowing water. The moraines are generally looked upon as lines along which the edge of the ice sheet remained stationary for a considerable length of time. While the ice gradually brought materials to such lines, the process of melting prevented its farther advance and the clay and gravel contained in it were dropped along its edge.

In this quadrangle there are portions of two systems of moraines. This is shown not only by the facts presented in the quadrangle, but also by the relations of the deposits to the moraines of adjacent areas. This quadrangle lies wholly within the area occupied by the advance of the ice sheet known to geologists as the Wisconsin, because its deposits are best represented and were first studied in that State. This was one of the more recent of the principal advances of the ice sheet, and, unlike earlier advances, marked its different stages by the formation of conspicuous moraines. These, however, are not so grandly marked in this area as in Wisconsin and in the northern part of South Dakota.

The oldest moraine of this area has been called the Altamont, from its development near the town of that name in South Dakota. Representatives of the earlier stages of that moraine are found in the central portion of Turkey Ridge, and in that locality they are not distinctly separated from those which, it may be presumed, were formed considerably later. The ridge constituted the first portion of the quadrangle to be uncovered as the ice sheet melted away, and doubtless the land first appeared from underneath the ice at its southern end. At that time, it seems, portions of three lobes of ice, as they may be called, were pushing southeastward from the thicker part of the glacier in the central section of the James River Valley. The broader of these lobes occupied the Vermilion Valley and extended from the central portion of Turkey Ridge eastward to the Big Sioux at Canton and northeastward to the East Coteau, a little beyond the northeast corner of this quadrangle. The eastern edge of the ice at that time rested along the high ridge lying directly east of Turkey Ridge, and extended from Beresford, in Union County, southward. The end of this lobe reached Missouri River at Vermilion. The middle lobe was about 8 miles wide and its sides were nearly parallel to and extended into and down the Missouri Valley at least as far as Gayville, although its deposits, if any were formed by it, have since been swept away by Missouri River. From Turkey Ridge westward the two lobes mentioned coalesced, forming one broad lobe. At that time no earth was uncovered in that direction nearer than the high hills northwest of Yankton. The third lobe, by which only a few square miles of this quadrangle were covered—in the extreme southwest corner—was moving directly eastward, and joined the second lobe northeast of Yankton. It is believed to have been connected a few miles farther north with the James River lobe, and its course of motion was changed from southward to eastward by the old valley of the Niobrara, which apparently was formerly located north of Yankton.

This hypothesis explains how James Ridge may be considered a later portion of the Altamont moraine, formed between the James River and Niobrara River lobes; also how the outer heavy drift deposits on the slopes of Turkey Ridge were accumulated during the same time, and why they are not distinctly separated from the older portion. It also shows why the hills in the extreme northeast corner of the quadrangle are of the same age.

In all of these lobes the movement of the ice was most rapid in the center, where it was toward the southeast or east, yet near the edge of the lobe the movement was at all points nearly at right angles to the edge, so that Turkey Ridge and James Ridge were gradually built up of material brought by the ice sheet and dropped as it melted away.

The Gary moraine, named from Gary in Deuel County, S. Dak., is not very strongly developed in this quadrangle, though it may be clearly traced across it. It enters the quadrangle on the northeast side of James Ridge as a series of low, choppy, knolly ridges trending southeastward and follows the east side of that ridge nearly to the southern boundary of the quadrangle, where it rises to a height of 60 or 70 feet, turns eastward, and crosses James River beyond the limits of the quadrangle. It reappears on the east side of the river in a ridge rising over 1400 feet above the sea, or about 100 feet above the surrounding country. The highest points in it are found near the southeast corner of sec. 27, T. 95, R. 55, whence it drops gradually to the level of the plain, which there bears evidence of stream erosion, turns a little to the northeast, gradually rises along the west side of Dry Creek, and is well developed between that stream and Clay Creek. It is here composed of two members, of which the second or outer member is higher and more continuous. It rises to the northwest and continues in nearly a straight line to the center of T. 97, R. 56, whence it gradually swings northward around the head of Turkey Ridge and culminates 2 miles south of Freeman at an altitude of 1640 feet. From that point it again gradually declines in altitude, but increases in width and swings to the northeast. It crosses the West Fork of the Vermilion about 3 miles east of Marion and turns northward, passing a little east of Monroe. It is separated from Turkey Ridge by the valley of Clay Creek on the west and by the upper portion of Turkey Ridge Creek on the north. It is best developed around the northwest end of Turkey Ridge. At some points it is flattened out into a plain, so that it can be traced only by occasional knolly ridges which usually trend in the direction of its course.

The bowlders of the Gary moraine are peculiar as contrasted with those of the Altamont, in which, on the high region of Turkey Ridge, especially near the north end, a great majority of the bowlders, sometimes as high as 90 per cent, are of red quartzite, while in the Gary moraine few or no bowlders of this rock can be found. Moreover, this distinction seems to hold in the comparison of the till sheets even within the second moraine; for example, along Wolf Creek and the West Fork of the Vermilion, red quartzite bowlders are abundant in the lower portion of the till where it is exposed in some steep bluffs, but they are very rarely seen in the upper portion of the same bluff. This fact seems to support the idea that the ice sheet of the first moraine was heavier and more vigorous in its action, and for that reason worked along on and cut down the surface of the red quartzite ridges farther north. In that stage of the ice the land was seemingly very uneven, and, owing to its jointed and stratified character, the surface rock was easily broken up and swept away by the ice; but during the second moraine deposits of till had begun to form underneath the ice and the process of erosion of rock ledges was prevented.

*Terraces and ancient channels.*—From the description already given of the supposed changes in the ice sheet, it is evident that at different stages of its occupation of the region there must have been some changes in drainage. Deflections of drainage courses seem to have been not so common as in adjacent areas, but there was considerable change of level and great variation in volume of water discharged. Terraces, sometimes well marked, often occur along small streams and dry water courses, indicating former copious streams. Though at present it is somewhat difficult to define the pre-Glacial drainage of the region in all details, a number of points may be stated with considerable confidence. While the James River Valley was doubtless occupied by a large stream before the advent of the ice, it is not clear that the West Fork of the Vermilion ever flowed across what is now the divide between the James and the East Fork of the Vermilion, nor is it clear that the East Fork was the main branch of the Vermilion. Possibly the Vermilion should be looked for as coming from the Big Sioux above Sioux Falls, but this is speculative. Without doubt, Turkey Ridge was a high divide between the James and the Vermilion, and its eastern edge probably extended nearly to the present course of the Vermilion. This may be inferred from the firmness of the underlying chalk and the thinness of the till along the east side of T. 95, R. 53, and also its nearness to the surface at Hurley. Moreover, the pre-Glacial Vermilion doubtless had an important tributary lying along the present course of Turkey Ridge Creek. So also, Frog Creek had a pre-Glacial existence. Perhaps the greatest change in course of streams is in the case of Beaver Creek in the southwest corner of the quadrangle.

The first drainage channel to be occupied on the retreat of the ice was that of Turkey Creek. From the geologic map it will be readily seen that it formed an outlet for the water flowing between the Vermilion and James River lobes during the later stages of the formation of the Altamont moraine. It may also be easily seen that the waters flowed in from both sides, although perhaps the greater amount came from the northeast. That this was the case is attested by the greater erosion along the eastern branch, which has cut down several scores of feet deeper than the tributaries from the west. The valleys of the western tributaries seem, in fact, to have been occupied for only a short time. Their valleys are usually shallow and broad. When Turkey Creek first began its course, it apparently flowed at an altitude of nearly 200 feet above its present level at the south end, as is indicated by remnants of a broad terrace appearing at that height. Moreover, the stream must have continued cutting until the ice had receded some distance north of Irene, for the water still ran through the channel from that direction. No stronger evidence can be found of the former occupation of the land by the ice sheet than these deep-cut canyons in the midst of those hills, with their headwaters extending toward the outer slopes of the ridge. At about the same time there was a peculiar channel formed across the upper part of James Ridge, extending from south to north along the east side of sec. 17, T. 95, R. 56. The deep gorge of Beaver Creek through the ridge had evidently not then begun, or if so it was not occupied, and the drainage from the James River lobe was toward the southwest. It is not unlikely that the gorge of Beaver Creek may have been begun by a stream flowing from east to west at about the same time.

As the margin of the Vermilion ice lobe withdrew northward the time arrived when the waters that were discharged down the east branch of Turkey Creek found an outlet toward the southeast, successively by (1) the channels starting northeast of Irene, (2) Frog Creek, (3) the channel west of Viborg, (4) Turkey Ridge Creek. By that time the ice had so completely vacated the Vermilion Valley that an extensive lake 4 or 5 miles wide existed east of Hurley.

Meanwhile the lobe pushing down the James River Valley shrunk and withdrew to the north, opening up in succession Clay Creek, Dry Creek, and Mud Creek. The extent of the withdrawal of the ice has not been determined, but probably it melted back some distance within the second or Gary moraine. Then there was an advance until the edge of the ice lay within the Gary moraine, as has already been stated.

During the occupation of the Gary moraine, the drainage of the west side of the James River lobe was along the east side of James Ridge. Very likely at first some of the water passed westward over the ridge and flowed along its west side, as during the later stages of the Altamont moraine, but soon the drainage below that point cut back a lower base-level, which was then extended upstream until the channel deepened and a portion of the original Beaver Creek was turned from its course south of James Ridge into a new channel. East of the James River lobe the old channel of Clay Creek was again occupied and cut down considerably below its former level, not only into the till but into the underlying chalk. As the body of the lobe diminished, especially toward the south, the ice withdrew and a new channel was formed along the present course of Dry Creek nearly parallel with Clay Creek. At the same time a portion of the ice lobe resting on the divide between the James and the East Fork of the Vermilion discharged copious streams southeastward along the channels that were probably located during the recession of the ice. These streams laid down much sand and gravel, along their courses and formed large deposits of gravel near Parker. At the same time Vermilion Lake, as it may be called, east of Parker, was filled with sand. In this work the West Fork of the Vermilion was assisted by the East Fork, which received water from the eastern branch of the ice for some distance farther north. As the ice receded from the Gary moraine, the drainage on the east side was mainly by the West Fork of Vermilion, which continued to form gravel deposits a few feet above the present stream. The drainage from the west side of the ice was mainly down James River, and similar deposits doubtless accumulated near the edge of the ice beyond the borders of the Parker quadrangle. The part of the James River channel in this quadrangle was at this time undergoing erosion.

*Osars.*—There are within the quadrangle certain narrow gravelly and sandy ridges, often arranged in a system more or less winding, like a river, and otherwise indicating their deposition by streams that attended the ice sheet. These are rarely over 15 feet high, are very stony on the surface, and are marked on the map at only three places, viz, in the northwest corner of T. 97, R. 54, at a point 2 miles north of Irene, and in the northern part of T. 96, R. 54.

*Alluvium.*—All the streams that traverse the region are subject to sudden floods, caused not only by occasional excessive rainfall, but by the rapid melting of abundant snow during certain seasons. The gravels of these ancient channels and lake basins, already referred to, are thickly covered with fine silt, which is in part due to the deposition of dust from the air. The alluvial plain of James River is about half a mile wide. Some portions of it are dry and are well adapted to cultivation; other parts are marshy, and all are more or less subject to occasional floods. The alluvial deposits are from 10 to 20 feet thick, the upper 3 to 5 feet being usually fine black loam, the lower portion sand.

## GEOLOGIC HISTORY.

As the area exhibits no rocks older than the later Algonkian, the earliest phases of the history of the region of which this quadrangle is a part may be briefly stated as follows: At some stage preceding the formation of the Sioux quartzite a land surface composed of granite and schist occupied central Minnesota, and possibly extended to the regions lying north and east of this quadrangle. From that land area material was derived, both by the action of streams and by wave erosion along the shore, which was laid down over the region now occupied by the Sioux quartzite. The deposit was mainly in the form of stratified sands, although occasionally thin beds of clay were accumulated. Possibly the deposits were laid down more thickly toward the center of the area, near the underground ridge of quartzite that now extends, as a broad peninsula, in a southwest direction, from the vicinity of Pipestone, Minn., and Sioux Falls, S. Dak. After such deposition there seems to have been an epoch of slight volcanic disturbances and igneous outflow, as indicated by the presence of a dike of olivine-diabase near Corson, S. Dak., and possibly also by the similar rock in borings at Yankton and Alexandria, S. Dak., and by a dike of quartz-porphyry near Hull, Iowa. Through silicification the sandstone was changed to an intensely hard and vitreous quartzite, and the clay beds were transformed into pipestone and the more siliceous red slate, as at Palisade. Microscopic examination shows that the silicification was effected by the crystallization of quartz around the separate grains of sand until the intervening spaces were entirely filled. The material of the quartzite was laid down in the sea, and at first may have included scores, or even hundreds, of feet of material above that which is now found. In time the region was lifted above the sea, and during some part or all of the long Paleozoic era it was a peninsula. At times it may have been submerged and have received other deposits, but if so, they have been eroded.

In this quadrangle, as throughout this general region, there is no trace of Paleozoic, Triassic, or Jurassic formations. The surface of the Sioux quartzite shows marks of long erosion at an elevation far above sea level. The Paleozoic rock nearest to this quadrangle, so far as has been discovered, was found in borings at Ponca, Nebr. and at Sioux City, Iowa. While the mountain masses of the Appalachian region and the extensive coal fields of the eastern part of the Mississippi Valley were forming, this area was probably a land surface. It is possible that soils and vegetation that may have then extended over it were removed by the advance of the sea during the Cretaceous period. At any rate, no traces of soil of any kind are found on the surface of the quartzite. As several hundred feet of strata of marine origin, representing all of Paleozoic time, are found in the Black Hills, the shore of the sea of that time must have extended across South Dakota somewhere west of the present course of Missouri River. Moreover, as the Triassic formation of the Black Hills testifies to an inclosed sea, barren of life, we must believe that during that epoch this inland sea was not connected with the ocean.

At the beginning of Jurassic time the land began to subside and the sea gradually advanced over central South Dakota, but apparently land surface continued until much of the Cretaceous period had passed, for the first deposits appear to have been sediments of Dakota time. These were mainly sands deposited on beaches and in estuaries, but, in intervals of quieter and deeper waters, clays were also laid down. The sands probably came in part from the disintegration of the quartzite along the adjacent shore, and it is likely that they were carried to and fro by vigorous tidal currents. The clay may be traced with considerable confidence to the soil and fine material that were being washed from the land as the waters continued to advance toward the east.

At the end of the Dakota the ocean waters overspread the region as far as southeastern Minnesota and the deposition of the Benton shales began. There were some short periods of shallow waters with strong currents which deposited local layers of sand, but clays were the predominant sediments. In Niobrara time the waters were deep and clear in the greater part of the area and extensive deposits of carbonate of lime accumulated, now represented by the chalkstone. At this time there was abundant life in the waters, including fish, huge reptiles, and mollusks. Deep waters and clay deposits continued during Pierre time, and probably several hundred feet of Pierre sediments extended across southeastern South Dakota. In the later part of the Cretaceous there were at first shallow ocean waters of Fox Hills time and then brackish and fresh waters in which the Laramie sandstones were laid down, but as these formations are absent in the area lying southeastward there is no evidence as to the conditions in southeastern South Dakota in this epoch. Presumably it was then a land surface, and probably the land surface continued during the Tertiary, when some of the streams of the late Tertiary spread local deposits of sand over portions of the region. If these ever covered any part of this quadrangle they have been removed by erosion.

During the latter part of the Neocene period there was doubtless a large stream flowing southward somewhere near the present position of James River and receiving the various streams from the west which now flow into the Missouri.

The Vermilion Valley also was occupied by a similar stream which may have been connected toward the north with the valley of the Big Sioux above Sioux Falls. It doubtless received tributaries from the northwest, one of which was the East Fork of the Vermilion, and another Turkey Ridge Creek, or at least streams having nearly the positions of those named. Turkey Ridge may be considered the southern end of the divide separating James and Vermilion rivers, and formerly extending in a zigzag manner past Marion and approximately along the line of the Gary moraine. It is not unlikely that its upper portion, being of the easily eroded Benton clay, had already become outlined. That the Vermilion, before the coming of the glaciers, had reached nearly its present level is attested by the occurrence of gravel deposits east of Centerville and at other points in the axis of the valley.

These were the conditions preceding the Ice Age, when the climate became moister and colder. During the earlier portion of the Ice Age, before and during the Kansan stage, the ice had not passed over the divide between James River and Red River, and hence the streams, though swollen by rains, did not receive water from the ice. If the ice reached the boundaries of this State, it did so probably in Minnehaha County, coming over from the Minnesota Valley, and Big Sioux and Vermilion rivers carried off the products of melting.

During the Wisconsin stage the ice finally passed over the divide, entered the James River Valley, and steadily progressed down the valley until it had filled it to a depth in the center of 1000 to 2000 feet. This ice sheet moved according to the slope of the pre-Glacial surface, moving more rapidly on the lower and more open portions of the valley and becoming almost stranded on the higher elevations. It certainly extended as far as the outer or Altamont moraine. Some geologists are confident that it extended down the Missouri Valley so as to become confluent with the similar sheet flowing down the Minnesota and Des Moines valleys, both of them together extending into Kansas and central Missouri. However that may be, we know that during the formation of the Altamont moraine it filled the whole James River Valley and extended westward at different points to the present channel of Missouri River, as near Andes Lake, Bonhomme, and Gayville, so that the Altamont moraine forms an almost continuous ridge or system of stony hills, which extended around the edge of the ice sheet of that epoch except where it was removed or rearranged by escaping waters. At this stage was formed the central part of Turkey Ridge. At that time the drainage was mainly down Turkey Creek and its branches, as has already been stated under the heading "Terraces and ancient channels."

Then, for some unknown reason, the ice began to recede. Whether the snowfall was less abundant at the fountain head, whether the ice streams found some other outlet from the shifting of the earth's surface or other cause, or whether the climate had become so much warmer that melting overbalanced freezing has not been satisfactorily determined. Nevertheless, we know that the edge of the ice receded and that at a later stage of the Altamont moraine there was deposited the higher part of James Ridge in the southwest corner of the quadrangle, and the hills in the extreme northeast corner. After this came a period of still more rapid recession, which carried the ice an indefinite distance farther north. It is not unlikely that its margin was considerably within the line of the second or Gary moraine. Then came a period of slight advance or standstill, while the edge of the ice rested along the line of the Gary moraine, as has already been described, and during that time the drainage was rearranged, as is indicated on the Areal Geology sheet and explained in the discussion of "Terraces and ancient channels." Finally the ice receded entirely, and the present drainage system was established.

The main geologic event since the disappearance of the ice sheet has been the formation of the soil. This has gone on by the deposition of alluvium along the principal streams, the wash of material from the hillsides, the settling of dust from the atmosphere, and the accumulation of vegetable deposits. The depth of the fine material has been increased by the burrowing of animals.

## ECONOMIC GEOLOGY.

No mineral ores of any sort are found in this quadrangle, nor beds of coal or lignite. Since the upper layers of the Dakota are known to contain thin and comparatively unimportant beds of lignite near Ponca, Nebr., and along the Big Sioux near its mouth, it is not impossible that thin beds may be found in well borings in the eastern part of this quadrangle. It is, however, improbable that any coal of real value will be found.

### BUILDING STONE.

The most abundant stone in the quadrangle is that brought by the glaciers of the Pleistocene. It is in the form of bowlders which are scattered over the greater part of the country, but are most abundant in the morainic areas. On Turkey Ridge they consist mainly of red quartzite; elsewhere they are of granite and limestone, with occasional trap rocks. They are not easily prepared for ordinary building purposes, because of their hardness and toughness, and thus far their use has been confined to laying foundations.

*Quartzite.*—The red quartzite or "Sioux Falls granite," as it has been called, extends into the northeast corner of the quadrangle, where quarries were opened several years ago, east of Parker. The stone varies at different localities in the thickness of the strata and the compactness of its structure. That east of Parker is more massive than that found at exposures in the northwest corner of T. 100, R. 53, where the layers are thin and the rock sometimes resembles ordinary sandstone. Other exposures are marked on the Areal Geology sheet, at any one of which quarries could be opened should there be any demand for the stone. It is a valuable stone for building, the medium-colored varieties being used for the main walls while the darker and lighter are used for trimming. It is practically indestructible. The chief objection to the use of the quartzite as a building stone is found in its hardness, which makes it difficult to work. Specimens of this rock found in Minnesota were tested among others of that State at Fort Wadsworth, Staten Island, under the direction of Gen. Q. A. Gillmore. For this purpose specimens of the rock were cut into cubes measuring 2 inches each way and subjected to pressure between steel plates, one specimen being crushed by pressure applied perpendicularly to the plane of bedding or stratification and another by pressure parallel to that plane. The strength shown in the first case was 27,750 pounds per square inch, in the second 27,000.

*Chalkstone.*—This occurs along the bluffs of Turkey Creek and Clay Creek, mainly in T. 95, R. 54, as is indicated on the Areal Geology sheet. The stone is as good as that found at other places, but has not been much used for the construction of buildings. From its use elsewhere, it may be said that buildings made of carefully selected material are known to be very durable. When freshly quarried the stone may be easily cut with a saw, and should be seasoned before it is placed in a wall.

### CEMENT.

Near Yankton, not far south of this quadrangle, an excellent variety of Portland cement has been manufactured from the chalkstone ground and mingled with the overlying dark clays of the Cretaceous. Similar combinations of material can be easily made at several points in this quadrangle. At a number of places where the chalkstone appears, the overlying dark clay is not present, but in the southeast corner of sec. 11, T. 95, R. 54, an exposure of the two in connection occurs, and it is probable that a little exploration would show a similar combination of deposits about a mile and a half farther south and also on or near sec. 20 of the same township.

### CLAYS.

Although the till is composed largely of clay, it is so mixed with gravel, and also with calcareous matter, that it has nowhere been successfully used for economic purposes, not even for the manufacture of brick. The Cretaceous clays are so little exposed that there has been no attempt to utilize them. It is probable that the clays already referred to as overlying the chalk might be satisfactorily utilized for the making of brick or even pottery. The Cretaceous deposits exposed in the quadrangle are mainly chalkstone. An attempt to make brick from the finer drift clay in the upper part of the Clay Creek Valley proved unsuccessful.

### SAND AND GRAVEL.

Plastering sand and gravel are found at a number of points, especially along the ancient channels and terraces. Gravel beds that have been worked extensively occur in the high terraces along the railroad east of Parker.

### WATER.

This resource is of prime importance. Perhaps the greatest of the benefits resulting from the geologic investigation of the region will be the determination of the distribution, character, and accessibility of its waters. They may be classified into surface waters and subterranean waters. The former include springs, streams, and lakes; the latter, wells, both pump and artesian.

#### SURFACE WATERS.

*Streams.*—James River, Vermilion River, and stretches extending a few miles along the lower courses of Turkey Ridge Creek and Turkey Creek are the only lines along which there is running water the year round. James River is a sluggish stream several yards wide and from 3 to 10 feet deep. Because of its steep banks and muddy bottom, it can rarely be forded and must be crossed by bridges. The water is more or less hard and presents the qualities common to surface streams. The Vermilion shows running water through most of its course in this quadrangle.

*Springs.*—Permanent springs are rare. One of the most notable occurs on a plain near the central part of the local artesian basin in the northeastern part of T. 97, R. 54. It is in the form of a marsh, and the opening of the spring is not well defined. It is evidently a natural outlet of the same waters that supply adjacent artesian wells. Several springs are found along Turkey Creek in the chalkstone region. The water comes from the lower portion of the chalkstone. Some fine springs occur in the ravines on the northeast slope of Turkey Ridge. Springs of less prominence are found along the sides of the channels of Vermilion and James rivers, where the water escapes from layers of sand or gravel, sometimes in the ancient terraces, at other times near the present level of the stream. These springs are likely to be not very permanent. No springs like those near Olivet, supplied from the water-bearing Dakota strata, have been recognized. It is not unlikely, however, that such may occur in the trough of James River below water level. Springs in the line of water courses, produced by the seeping of the water through the sand filling the lower part of the channel, are found along Clay Creek, Turkey Creek, and similar streams. Water holes or basins having no visible outlet are in the same way supplied with comparatively pure water. The influx of water from the sand and its underground escape produce motion sufficient to keep them from stagnating, especially in the upper portion of the watercourses.

*Lakes.*—These receive their waters directly from the rainfall and endure according to the extent of their drainage basin, their depth, and the rainfall, which varies greatly. It averages from 25 to 30 inches a year. After a succession of wet years the lake beds over the whole region are full of water and are usually more or less filled in the spring, especially if there has been much snow. In the latter part of summer a great majority of them become dry. A few of the more permanent lakes or ponds are marked on the map. Among these may be mentioned Lost Lake, which covers at ordinary stages most of sec. 25, T. 100, R. 56; Swan Lake, which is located in the central portion of T. 97, R. 53; and Mud Lake, 2 miles east of Hurley. Besides these, a number of almost permanent lakes are found on the higher portions of Turkey Ridge.

#### SUBTERRANEAN WATERS.

Waters obtained from below the surface by artificial means will be considered under the headings "Shallow wells," "Tubular wells," and "Artesian wells."

##### SHALLOW WELLS.

By shallow wells is meant those which are supplied from water that has recently fallen on the surface and which can be sunk without penetrating an impervious layer. The most common source of supply for these wells is the water that lies near the surface, and seeps through the upper portion of the till toward a watercourse wherever there are shallow accumulations of sand that form conduits for it. The water flows slowly through the lower portion of these sand accumulations and appears at intervals in water holes along the upper courses of the more prominent streams. In these it rarely comes forth in sufficient strength to attract attention. Where the slope of the surface is toward an undrained basin, the water of the yellow till flows out and forms a lake, so that the general water level sinks, a condition which often exists. It may then be drawn upon by shallow wells, which for a number of years may be entirely adequate for the demands of neighboring farms, but in time of drought it is gradually exhausted. Where the surface slopes toward a watercourse the water accumulates in larger quantity, but it also flows away more quickly. Shallow wells, therefore, along the ancient watercourses that were occupied by streams of considerable size during the presence of glaciers in the vicinity, afford the most copious water supply. When the region was first settled these shallow wells were the main dependence of the farmers. In 1881 and a few years later, water was abundant in these surface wells, but after a series of dry years this supply became exhausted and the farmers were forced to go deeper in order to obtain water.

### TUBULAR WELLS.

Under this head will be included simply the deeper wells, in which a tubular or force pump is usually necessary. The water frequently rises nearly to the surface and occasionally flows. These wells are from 100 to 300 feet deep, and derive water mainly from the sand and gravel at the base of the drift. This depth would be a serious disadvantage were it not in a measure compensated by the rise of the water, which in many of these wells stands within 5 to 25 feet of the surface. Some, in fact, are flowing wells, as shown on the Artesian Water sheet. There are in the quadrangle wells of this class that have been flowing for over twenty years. The approximate depths to the bottom of the till in different parts of the Parker quadrangle are shown in fig. 6. It should be remembered that there are many local variations of small amount which can not be represented on a diagram of this character, and, moreover, the sub-till sand sheet is not everywhere filled with water, especially in the more elevated regions. Therefore, a boring may pass through the sand to the Cretaceous shales below without obtaining water. Some wells on Turkey Ridge seem to have done this. On the other hand, flowing wells have frequently been found in the deeper strata. The areas where flowing wells from this source have been obtained are indicated on the Artesian Water sheet. The largest area is near the center of the quadrangle. Other large areas are on the western margin and smaller ones occur scattered through the southern and eastern portions of the quadrangle. Probably flowing wells of this character will be found at other places, especially at middle altitudes remote from important streams. In some cases the erosion of the ravines or watercourses renders the flowing wells possible by decreasing the altitude of the surface while the head remains constant. Deposits of sand and gravel that are locally developed in the till frequently furnish a copious supply of water. In such cases wells obtain abundant water without passing through the till. On the other hand, the sands below the till are often absent. In such cases no water is likely to be reached short of the main artesian supply.

The deep wells supplied from the basal sands of the drift are commonly known as tubular wells. Hence the Pleistocene sands may conveniently be spoken of as the "tubular-well supply."

The original source of this supply is the rainfall, the same as in the case of shallow wells, but it is a more constant supply because the water enters it more gradually. It is more continuous and does not waste in evaporation, as in the former case. It should not, however, be considered as inexhaustible. If the supply is drawn upon too freely it may be expected that these wells will gradually fail, beginning with those in the more elevated areas.

The way in which the water enters this stratum is not well understood. In general, the till seems to be so perfectly impervious, especially at lower levels, that it completely prevents the escape of the water below. There are, however, joints in the clay which at certain times, especially after drouth, are probably opened sufficiently to allow some water to enter from the surface. Besides, it is not improbable that the bottom of the ancient channels may, at some points, cut through the till to the lower Pleistocene sands in such a way as to add materially to this supply.

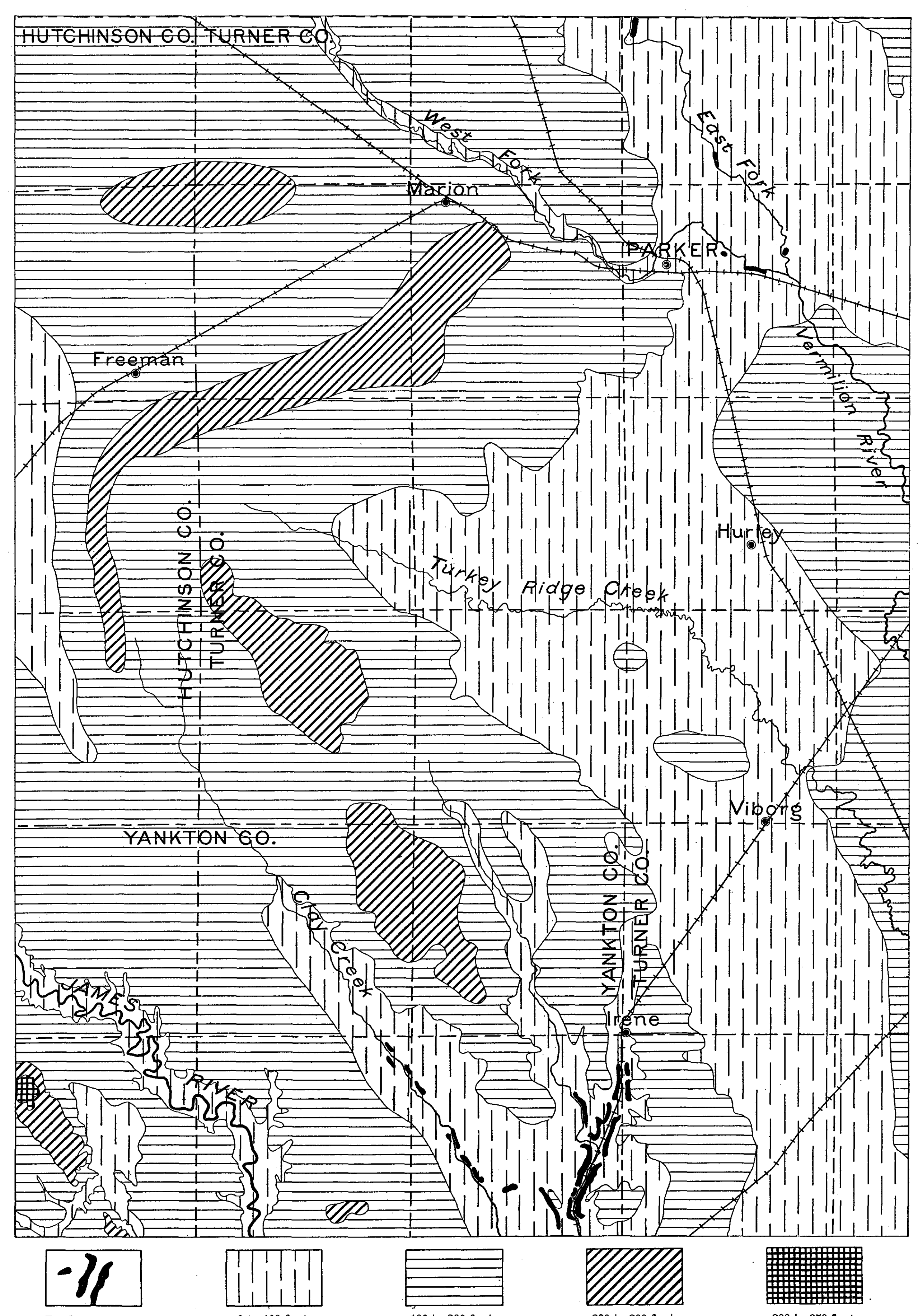


FIG. 6.—Sketch map of Parker quadrangle, showing approximate depths to the bottom of the till. The sand at the base of the till usually yields water which generally rises many feet in wells.

### RETENTION OF THE RAINFALL.

From the discussion of underground waters, it is evident that both the shallow wells and the tubular wells are replenished by the retention of rainfall. Hence it is advisable, and in many cases practicable, to build dams across shallow watercourses in such a way as to make ponds, the water of which will gradually sink into the ground and reach these wells. The advantages of this are obvious. In the Parker quadrangle, the upper courses of Clay Creek, Turkey Ridge Creek, and several smaller streams, as well as ravines descending from Turkey Ridge, might be made reservoirs, which would be of advantage not only by retaining the water in the adjacent ground but by encouraging the growth of trees that might be planted about them. The only disadvantage suggested is the occupation of otherwise valuable ground, but this would certainly be more than compensated for by the increased value of adjacent land in any ordinary year.

### ARTESIAN WELLS.

*Subordinate water horizons.*—In this quadrangle there are no deposits of Tertiary sand under the drift except on Turkey Ridge, and these are not likely to be discriminated from the basal sands of the drift, which supply the tubular wells. The Niobrara chalkstone is porous and water bearing; in fact springs are occasionally found flowing from it. This is especially true along the lower course of Turkey Creek. It also exists in detached masses, and wherever it affects wells it is so closely beneath the drift that it need not be considered at any length apart from the tubular-well supply. Many tubular wells, especially outside of this quadrangle, seem to obtain their water in the chalkstone underneath the sands.

It has been found convenient to use the chalk as a filter to keep out the sand from the bottom of the well. Moreover, in some places, although not in this quadrangle, there is a stratum of sandstone in the chalk, or next below it, that affords a copious supply of water. Flows of greater or less volume are also found in the lower sandstones of the Benton formation. These are described with the Dakota flows under the next heading.

*Main artesian supply.*—The main supply of artesian water in this region is undoubtedly derived from the sandstone and sand beds of the Dakota formation. This remarkable formation is the source of artesian water not only under much of eastern South Dakota but in a wide area in adjoining States. It owes its efficiency to four factors: (1) Its great extent, underlying most of the Great Plains from the Rocky Mountains eastward to about the ninety-fifth meridian; (2) its highly elevated western border, located in the moist region of the mountains and crossed by numerous mountain streams; (3) its being extensively sealed in its eastern margin by the overlapping clays of the Benton formation, and where they are absent by the till sheet of the Glacial epoch; and (4) the cutting of wide valleys, especially in Dakota, by pre-Glacial streams, so as to bring the land surface below the pressure height or "head" generated by the elevated western border of the formation. From this formation is derived a copious pumping supply over wide areas where the pressure is not sufficient to produce flowing wells.

The Dakota sandstone probably underlies only the central and southwestern half of this quadrangle, and fig. 7 shows the wells in the southwestern portion penetrating to the water-bearing stratum. From the relation of pressure and altitude of the surface the area of artesian flow is limited to the portion shown on the Artesian Water sheet.

In boring wells, a water-bearing stratum in which the water is under pressure is generally spoken of as a "flow" and the well is classed as "artesian," although some persons would limit the term artesian to wells in which there is sufficient pressure to raise the water to the surface. From a comparison of the sections of different wells, it appears that the sand in the Dakota formation is more or less divided into sheets by intercalated beds of clay, the permeable sandy deposits extending out in wing-like sheets. There are in this region at least three well-marked flows in the Dakota formation, besides one in the sandstone of the Benton, but in this bed the water is not under sufficient pressure to produce flowing wells in the vicinity of its exposure, and probably not in this quadrangle. On the Artesian Water sheet the depths to the highest water-bearing stratum are indicated by patterns, and the areas in which flows may be expected are shown by distinctive coloring.

From a comparison of depths, pressures, and amount of flow, it is inferred that not only are the water-bearing sandstone beds mainly in sheet form but these sheets rise as they approach elevated portions of the underlying quartzite, against which each sandstone abuts along a line marking the position of the seashore at the time the sand was deposited. Hence the lower beds do not extend so far north and east as the upper beds and are more closely sealed along their eastern margin. It is not impossible that, by the interpretation of carefully taken pressures, evidence may be found showing that different water-bearing sandstones communicate imperfectly with one another along the contact of the quartzite. As the sandstones lie in widely extended sheets, with intervening deposits of shale or clay, they doubtless vary greatly in continuity, porosity, and relative position; hence a sandstone that affords a flow in one locality may thin out and its waters may lack sufficient head to flow in another locality. Moreover, any estimate based on a comparison of simple depth may be misleading, because of the very gradual slope of

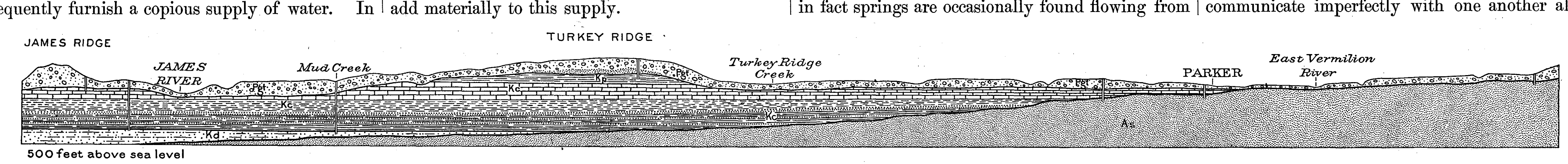


FIG. 7.—Sketch section across the Parker quadrangle along the line A-A on the Artesian Water sheet, showing the artesian wells in the southwestern portion penetrating to the Dakota sandstone. As, Sioux quartzite; Kd, Dakota formation; Kc, Benton formation overlain by Niobrara chalkstone; Kp, Pierre shale; Pgt, glacial till.

Horizontal scale: 1 inch=3 miles. Vertical scale: 1 inch=1500 feet.

the surface, which, although it appears to be a level plain, in fact often slopes 20 feet or more to the mile.

The number of flows and the distance between them become important questions to those who may desire to sink wells near the margin of the artesian area. If the uppermost water-bearing stratum has not sufficient pressure to force the water to the surface, the drilling must be continued until another stratum with sufficient head is reached. In the colored areas on the Artesian Water sheet showing depths to the water-bearing beds appear irregularities which are largely from this cause. Other conditions, however, conspire to produce irregularities. At least five factors affect the problem, viz: (1) The altitude at the point considered; (2) the pressure in the underlying water strata, which decreases in all strata toward the direction of freest leakage, and increases with the depth of the strata below the surface; (3) the dip of the strata, in this quadrangle usually toward the southwest, which though not great, must be taken into account; (4) the number of underlying water-bearing strata, which is usually two or three; (5) the vertical distance between successive strata. According to the reports of wells in the vicinity of the lower James River Valley the more important strata are from 75 to 100 feet apart. This appears from the following data: In a well in NW. ¼ sec. 34, T. 97, R. 57, there are flows at 300, 400, and 475 feet; at the Excelsior Mill well, Yankton at 300, 375, and 450 feet; in sec. 20, T. 94, R. 54, at 230 and 300 feet; and in the southern part of T. 95, R. 54, at 250 and 500 feet, with a faint flow between. The cement company west of Yankton reports flows at 375, 390, 405, 433, and 450 feet, indicating either subdivision of the usual flows or confusion of facts. Most wells show fewer than three flows, hence, in the western part of T. 95, R. 55, it has been assumed that the middle stratum of the three is so weak as to be ignored. This harmonizes with the records of wells a few miles east and explains why the few wells a little farther west had to go so deep.

*Amount of flow.*—Artesian wells vary greatly in the freedom with which they supply water. Compared with the larger wells those of small diameter, because of the greater friction of the smaller pipe, afford a supply much smaller than the ratio of the squares of their diameters would indicate. It may be thought that differences in copiousness of supply are primarily due to differences of pressure, but this is not the case. For example, some wells in the vicinity of Letcher, in the Mitchell quadrangle, deriving water from the second water-bearing sandstone, afford only a small flow from a 2-inch pipe, and yet the pressures run up to 50 or even 70 pounds; while others in the vicinity deriving their supply from the third water-bearing sandstone afford several hundred barrels a day with less than half the pressure. The primary factors, therefore, regulating the amount of discharge are the porosity of the water-bearing stratum and the perfection with which the well is kept in communication with the stratum. This explains why wells from the same bed differ greatly in the freedom of their discharge. The amount of flow is dependent not only on the factors already mentioned, but also on the thickness of water-bearing rock penetrated by the pipe at the bottom of the well; hence if a well strikes the thin portion of the water-bearing bed it is impossible to obtain as great a flow as where a thicker portion is penetrated, other things being equal.

*Quality of the water.*—The water from the Benton and Dakota sandstones varies considerably in quality, in some cases being largely charged with mineral matter, carbonate or sulphate of iron, and carbonate of lime, etc., but in no case to such extent as to be injurious to stock or unwholesome for drinking purposes.

*Artesian pressure.*—From a superficial study of artesian wells some people may have obtained the notion that all the artesian water in a basin has the same head or rises to the same plane. Such, however, is far from true, particularly in North and South Dakota. In general the pressure declines toward the margin of the water-bearing strata. This fact is readily explained in shallow basins by supposing that the water is moving as a slow current toward outlets or leaks along the margin of the formation, where the latter laps against the older rocks or where fissures may connect it with the bottom of streams. Each flow, in general, shows this same decline in pressure toward the northeast.

Moreover, from the relation of the Dakota formation to the Sioux quartzite and the Benton shale, the fact that the lower flows have higher pressure is easily understood. Their leakage is much less free. On the Artesian Water sheet there are contours representing the altitude or "head," which, in its downward slope eastward, may be regarded as a "hydraulic gradient." From the nature of the case, it would be impossible to represent the pressure for each water-bearing stratum; therefore the data from the more important wells have been taken; or, in other words, the lines of altitude of head may be taken as representing the relative pressure in the more available and accessible stratum. It is not unlikely that the sinking of wells from 300 feet to 500 feet in depth, to the third or fourth flow, may show considerably increased pressure. It will be observed that the lines have a distinct curve around toward the south and east. This may be ascribed to the influence of locally increased leakage along James and Missouri rivers.

The pressure in the wells of this area has not been very generally noted. Many of the wells are small and are used simply for farm supply, so that pressure has not been an important consideration. The contours of pressure on the Artesian Water sheet are estimated largely from a few deep borings beyond the limit of the artesian area. The height at which the water stood a few years ago when the survey was made has been approximately learned. Of late years it has stood lower. Some of the wells indicated on the map have lately ceased to flow.

*Varying pressure.*—In general the pressure increases with the depth to sandstones lying successively lower. This is true mainly because there is less chance for leakage along the eastern margin of the lower strata, but possibly also because of the higher altitude of the lower beds along their western margin in the Black Hills and Rocky Mountains, where the water enters. While the above rule holds in a great majority of cases, there are some marked exceptions.

*Cause of apparent decline of pressure.*—It is a fact now generally admitted that the flowing wells have not only decreased in flow but also that their pressure has declined. This becomes evident without direct measurements, first by a shortening of the distance to which the water is thrown from a horizontal pipe, and later by the fact that a stream which at first filled a pipe gradually fails to do so. In some cases a test with the gage shows that this is merely a decline in amount of flow without material decline in pressure, but in many cases the pressure is also found to be markedly diminished.

These facts suggest the partial exhaustion of the artesian supply, but it is claimed, and the claim is partially substantiated by facts, that the new wells frequently have a pressure equal to that of the early wells supplied from the same water-bearing bed. Since the closed pressures, however, are less frequently taken than formerly, and, from the nature of the case, liberal allowances are sometimes made for leakage, it is difficult to prove this.

In many cases diminution of flow results from the clogging of the well. As the wells are usually finished by resting the pipe on a firm stratum at the bottom of the well and perforating a portion of the pipe corresponding to the thickness of the water-bearing stratum, it will be readily seen that the surface open for the delivery of water to the well extends through the whole thickness of that stratum. As the water continues to flow, sand will accumulate on the inside of the pipe and so gradually diminish the surface supplying water at the well. Something of the same sort may less frequently occur even when the pipe is fastened in the cap rock above the water rock and a cavity made in the rock. As time passes sand gradually works in from the side and possibly portions of the cap rock are undermined and drop down, partially filling the cavity, so that even in such cases the freedom of the water is considerably checked.

Theoretically, the closed pressure should be the same whether the well is flowing freely or not, so long as the head of the water is the same. If the well becomes clogged, as suggested above, the only difference in the pressure should be that when a gage is attached it takes longer to reach the maximum point. As this rise may be very gradual, some errors of reading are likely to result because the observers have not waited long enough.

Another cause of decline of flow is leakage. This may be due to imperfect jointing of sections of the pipe or it may occur outside the pipe; and the leakage may be either above, at, or below the surface of the ground. As is well known, pipes deteriorate materially under the influence of most artesian water, and it becomes almost impossible to close their joints perfectly. Where any considerable extent of piping is included in the circuit, as in the case of the distributing pipes of a city, one can never be sure that all leaks are stopped. Doubtless the seemingly diminished pressure in many older wells is due to leakage.

The diminished pressure in a particular well may sometimes be only apparent and may result from the opening of another well not far away. In such a case no real closed pressure can be obtained unless both wells are closed at the same time. The distance to which this influence may extend will of course be greater where the water-bearing stratum is of coarse texture, and the usual supply of the water therefore more free. For example, at Letcher there are two wells not far apart which are of the same depth. The pressure of either taken alone is about 40 pounds, while about a mile away another well supplied from the same water-bearing bed shows a pressure of 55 pounds, and one 2 miles away shows 65 pounds. The diminished pressures reported from Mitchell, Mount Vernon, and Plankinton are very likely due to the multiplication of wells in particular areas. Moreover, in cases where water has been drawn freely from several wells there is no doubt a local depression of head which it takes considerable time to restore, possibly several days with all the wells closed.

Notwithstanding all the considerations offered thusfar, it seems not unlikely that the rapid multiplication of wells in this quadrangle would reduce the pressure, and it is therefore important that facts should be collected to ascertain whether this is thecase, and, if so, to determine the amount of diminution.

In view of the possibility of overtaxing the supply, it would seem desirable to limit in some way the number of large wells that are allowed to flow freely. A single thousand-gallon-a-minute well would be sufficient to supply 144 wells, one to each quarter section in a township, each furnishing 285 barrels a day or 7 gallons a minute, which would be an abundant supply for an ordinary farm. As it is, some large wells have been drilled with the intention of irrigating from them, and sufficient rainfall of late years has rendered them worse than useless, for considerable areas have been reduced to unproductive marshes from the overflow.

## SOIL AND VEGETATION.

There have been no careful analyses of the soils of the region, and only some of the more obvious characteristics can be noted here.

In general the soil may be said to be rather uniform and to have the characteristics common to that of most drift regions. It is generally a black loam, fertile and easily tilled. The subsoil is sufficiently clayey to keep the moisture from leaving the surface, and yet loamy enough to prevent caking under ordinary treatment. There are some localities, however, where the the soil is of a different character. The terraces along the ancient channels are frequently gravelly. The morainic areas are often so stony that large quantities of bowlders have to be removed from the fields. In some portions of Turkey Ridge red quartzite bowlders are found piled up around fields, reminding one in a mild way of the stony fields of New England. In some places the subsoil is too sandy for agricultural purposes. This is particularly true of the northern part of what is marked upon the Areal Geology sheet as an old lake bed northeast of Hurley. In the northern half of this lake bed there is a thick deposit of sand and gravel beneath which the water lies at such a depth that it is not easily reached by the roots of plants, and the formation is too porous to support vegetation. In moist seasons short grass grows abundantly on it, but after the rain ceases it quickly becomes dry. Farther southeast, immediately southeast of Hurley, the level-topped deposit is of finer grain and prevents the water from withdrawing so completely from the surface. About Swan Lake and in the valley of Turkey Ridge Creek are other filled lake basins that present in places sandy patches but in general more clay, so much that the ground is flat and inclined to be marshy, and the soil often so clayey as to require special care in tillage. In the southern part of the quadrangle, on the sides of the gorge of Turkey Creek and Clay Creek, are considerable areas so charged with the products of the weathering of chalk that they are comparatively barren. In part the barrenness of the soil at these places is due to the mineral constituents of the chalk, but more to its porousness, which prevents the retention of moisture.

The prevalent grasses of the region are species of blue joint (*Agropyron*), which grows wherever the land is moderately drained, and marsh grass (*Spartina*) which is found in the basins and on the alluvial bottoms of streams. On the sandy and gravelly areas and on the higher points generally, patches of the shorter grasses known as buffalo grass (*Bulbilis* and *Boutelona*) appear, but in general the climate of the region is too moist for their permanent growth.

Groves of considerable size are found along the bluffs of James River, in the gorges in the southern part of Turkey Ridge, and at a few points in the ravines on the northeast slope of the same ridge. The prevalent species may be named in the order of their prominence as follows: Cottonwood, elm, ash, and willow, the latter taking the lead where moisture is abundant. The natural groves were mostly removed in the early settlement of the country, but artificial groves were early planted and have flourished throughout the region.

August, 1903.