GEOGRAPHY.

General relations.—Eastern South Dakota is in the Great Plains province, in the broad, indented zone wherein these plains merge into the prairies of the Mississippi Valley. It is comprised within the area of glacial retreat, and most of its surface features show the characteristics of a drift-covered region. The country is mostly level, or presents rolling slopes rising out of broad expanses of plains. The principal elements of relief are long ranges of low hills, due to morainal accumulations left by the ice along lines marking various phases of glacial advance and retreat. Further diversity of topography has been produced by the excavation of the valleys, especially that of the Mississippi, which has cut out an arched valley hundreds of feet deep, nearly up to steeply sloping sides. Between the moraines there are rolling plains of till and very level plains due to the filling up of glacial lakes. Upper James River Valley presents a notable example of this lake-bottom topography.

Location.—The Mitchell quadrangle embraces the center of a square degree which lies between parallels 43° 30' and 44° north latitude and meridians 98° and 98° 30' west longitude. It measures approximately 53 miles from north to south and 265 miles from east to west, covering about 863 square miles. It includes portions of Yankton, Sully, and Jerauld counties, R. 56, and lies almost entirely in James River Valley.

Topography.—The general surface of the quadrangle is a nearly smooth plain that slopes northward and is broken only by the beds of streams, which have banks of moderate height. The highest elevation is in the central part of T. 101 N., R. 62 W., where the altitude is 1800 feet above sea level. The lowest elevation, 1220 feet, is in the James River bottom, in T. 104, R. 60.

Extension across the quadrangle from the northwestern corner to the southeastern end is a nearly straight line. The western border coincides with the upper portion of Firth Creek and the upper course of Ency Creek and continues southward along an old stream channel past the center of T. 101, R. 60. The eastern border of this belt is less definitely marked, but coincides in a line that begins where the western boundary of Samborn County enters the quadrangle, and extends southwesterly through the center of Mitchell County. This terminal belt consists largely of quarter mile of low, low ridges trending southward and nearly resting on more than 15 feet above the surface. The general belt is about 4 miles wide, and may be separated into three or four divisions by streams and winds. It is traversed by numerous old, flat-bottomed channels, which become especially noticeable toward the southeast.

The country lying southwest of the quadrangle has a smooth surface except in Aurora and Truro townships, where the land rises to the south and breaks off sharply into the head of Lake Andes Creek. The northeast is almost level and presents extensive areas of grassed prairie. The depressions have a depth of 10 to 15 feet.

At this elevation the surface of the rock is nearly level, covered with a mantle of glacial drift consisting of gravel, sand, silt, and clay, varying in thickness. The deep drift, which is described under the heading "Drift," shows well-pronounced joints running northwest. The numerous deep wells which have been a land surface during all of Paleozoic time present considerable importance in connection with the water supply, since it is the lower limit of the deep water of the region. The configuration of the surface of this rock within the quadrangle is represented by contours on the Artesian Water sheet. From these contours it is evident that the area comprises several square miles lying north of the Central Valley, which has an area of about 863 square miles. It includes portions of Yankton, Sully, and Jerauld counties, R. 56, and lies almost entirely in James River Valley.

Algonkian System.

Granite.—The oldest formation known in the quadrangle is a dark-gray granite, which was emplaced at a depth of 600 feet in a well in the SW 1/4 of sec. 35, T. 103, R. 61. It probably underlies the Sioux granite in other portions of the region, which would indicate Archean age, but it may possibly be an eroded rock, similar to that which has been exposed near Corson, R. 63. In the well at Mitchell no granite was struck, although the quartzite was penetrated and limonite was found. Sioux quartzite.—Next to the deeply buried granite, the oldest formation known in the region is a very hard, dark-purple or red quartzite, popularly known as the "Sioux Falls granite" or "jasper," and it is so represented in almost all older maps of the region. This rock has been reached in several places where the contours are properly drawn, but it is believed that the larger outlines do not correctly represent the thickness of the rock at any particular spot. The map gives only the general outlines, and local variations of 100 feet, either more or less, will be probable. The deep quartzite at Mitchell is indicated on the map, but it is not shown on the Artesian Water sheet. Above the quartzite is a thick mantle of fine sand, which increases in thickness from the west to the east. This sand probably underlies the region, but it is at present only a mapped formation.

General Geology.

The surface of eastern South Dakota is in large part covered with a mantle of glacial drift, consisting of gravel, sand, silt, and clay, varying in thickness. The deep drift, which is described under the heading "Drift," shows well-pronounced joints running northwest. The numerous deep wells which have been a land surface during all of Paleozoic time present considerable importance in connection with the water supply, since it is the lower limit of the deep water of the region. The configuration of the surface of this rock within the quadrangle is represented by contours on the Artesian Water sheet. From these contours it is evident that the area comprises several square miles lying north of the Central Valley, which has an area of about 863 square miles. It includes portions of Yankton, Sully, and Jerauld counties, R. 56, and lies almost entirely in James River Valley.

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In northern South Dakota there are several prominent exposures of the Dakota formation. The general section includes an upper and a lower shale bed, with thick sandstone between. The upper shale bed is occasionally absent, particularly in the northern portion of the quadrangle, and in the lower shale there is a second, thinner sandstone bed underlaid by a very thin siltstone. The band members of the Dakota formation consist of 100 feet or more of gray and black shale, indistinctly stratified in places. The Dakota formation is a prominent unit in the southeastern South Dakota region.

**South Dakota.** Within the quadrangle it nowhere occurs near the surface than about 200 feet. The sandstone outcrops at several points in the quadrangle and mapped as Dakota on the Geologic Map of the area. The outcrops are usually small, brown sandstone, hard and massive below, but somewhat banded above, having an average thickness of 100 feet. It varies from fine grained to coarse grained and usually is only moderately compact. It is usually of a drab color except where it has been exposed along Missouri River it is estimated to consist of about 50 feet of sandstone and 10 feet of shale lying on sandstone. Its water-bearing capacity is decidedly reported from several wells not very remote from this region, and such leaves have been found in the sandstone near Sioux City.

**Colorado Group.**

The Colorado group exhibits two quite distinct formations. The first or lower is called thelegant sandstone, so named because of its prominent development in the southeastern South Dakota region. The Colorado group is the principal water-bearing portion of the formation. In Davison County the Dakota appears to extend from a thicknesses are variable and diminish rapidly to 775 feet beneath the surface, without reaching the base of the formation. In the western portion of the formation the thicknesses are variable and diminish rapidly to 775 feet beneath the surface, without reaching the base of the formation. In the western portion of the formation the thicknesses are variable and diminish rapidly to 775 feet beneath the surface, without reaching the base of the formation. In the western portion of the formation the thicknesses are variable and diminish rapidly to 775 feet beneath the surface, without reaching the base of the formation.
The chalkstone is exposed at many points along James River and its winter tributaries, as may be seen on the geologic map. It often rises in cliffs 15 to 20 feet above the adjacent streams, and so it is quickly distinguished when moist and exposed to freezing, it more frequently appears as a steep-slope channel marked by a winding, meandering channel and terrace deposits. In the central, eastern, and southeastern portions of the quadrangle the chalk is often conspicuously developed and appears in many exposures that occur at intervals of a mile or so along Firesteel Creek, from its mouth to a point north of Mount Vernon. In some places the chalkstone and sandstone of the upper Benton appear in the same vertical section. For 5 or 6 miles west of the railroad crossing of Firesteel Creek, sections of chalk and sandstone alternate at about the same level, suggesting an unconformity. Whether this is due to the cessation, to change, or to some irregularity in deposition has not been surely determined, but hardness is the most probable cause. Exposures of chalkstone appear in a cut between the channels of Enemy and Twelvemile creeks, in T. 102, R. 42 (Foote Township), the chalk appearing in a steep bank facing northwest, where the lower portion shows beds of unusual hardness. Its texture here is distinctly marine in character and indicates that this stratum is a part of the Benton. Other Benton fossils were found in the Ashmore and Farrell wells, in the Alexander quadrangle.

From the black clay above the sandstone, north of Mount Vernon, a saurian vertebra about 4 inches long, 1 1/2 inches wide, and 1 1/4 inches thick, the most characteristic feature of this formation is its exposure from the surface. The uppermost portion of the formation. The greatest thickness is in the southwestern part of the quadrangle, where over 200 feet is occasionally reported. Possibly this includes the upper part of the overlying shale, and associated with the chalkstone. The formation rises on the slopes of the underground karstic ridge. Over its crests the upper member was removed by erosion before the ridge was covered by glacial drift.

The formations below and above are clay, the usual distribution of the Niobrara cannot be seen sharply defined in this drift-covered region. It is especially important to note in the different beds in clay, for the chalk has not been exposed to atmospheric action, and has a brown color, closely resembling the gray clays of the Benton. Occasionally fragments of wood have been reported from it, but in every case, when isolated into, they proved to be isolated pieces and not parts of a structure.

The surface of the till shows the characteristic irregularity common to it elsewhere. There are many small, irregularly shaped hills or knobs and minor basins without outlet. These features are finer than usual, and the general surface is much more nearly that of an undulating plain than is common in drift-covered regions. The reason for this seems to be that the proglacial Mother was active before the ice for a long period, and the underlying rocks being soft and somewhat uniform in character, the surface was planed down rather evenly.

There has also been a considerable amount of filling of the minor basins with soil, laid down by streams or peat, but these are thin, and the surface is now nearly as it was left by the ice sheet. Southwest of the morainic area there is a strip, 3 or 4 miles wide, which is nearly level, especially toward the southwest, where it also broadens. This strip shows a gradually increasing rise toward the southwest, attaining a depth of 25 feet, and with the thin surface of the ice sheet to have been covered by a thin sheet of water. In some localities considerable till has been deposited by the wind, but this influence has not modified the till of this region much, so that its surface is nearly as it was left by the ice sheet.

The upper surface of the Benton rises to nearly 1300 feet in the vicinity of Mitchell, and north and south of Plankinton it rises higher than 1300 feet, judging from the reports of well drillers. Its thickness may be estimated to be 200 to 350 feet, an average being about 250 feet. Near and on the underground quartzite ridge north of Mitchell it thins somewhat, 150 feet being its average thickness across the crest of the ridge.
road just east, it is found that the sandstone is mostly at the eastern margin of the Dakota formation, exposed just north.

As the moraine became more advanced, sandstone ledges were removed and the present waterways, for the latter are generally with the present waterways, but sometimes both basins and hills are very gently inclined, so that the whole constitutes a broad and steep ridge. The moraine is traversed here and there by valleys through which water escaped from the ice sheet. These may be of very small size or many miles in width, and may cut down to the bedrock below.

The topography of the moraine in this quadrangle is mostly of subdued type. During its formation the ice sheet was comparatively thin; the drift consisted largely of clay, and the discharge of water was not free. At a few points, especially toward the northern part of the quadrangle, the moraine presents a high, even surface, which is nearly parallel to the present water. In the southern part of the TWINER, small ridges rising 15 to 20 feet above the lowest parts of the valley of Enemy Creek, are scarps or abrupt ridges rising more than 30 feet above the valley bottom. The moraine appears to be formed of two distinct formations. The first, which is the lower of the two, is broader and higher than the other, and is the more distinctly morainic in character. The second, which is the upper, is more irregular in outline, and is characterized by the presence of large amounts of coarse material. It is probable that the lower formation is that which was formed during the early stages of the Wisconsin glaciation, and that the upper formation was formed during the later stages.

The moraine presents a high, evenly formed swell-ridge. The development of this moraine is mostly of subdued type. During its formation the ice sheet was comparatively thin; the drift consisted largely of clay, and the discharge of water was not free. At a few points, especially toward the northern part of the quadrangle, the moraine presents a high, even surface, which is nearly parallel to the present waterways, for the latter are generally with the present waterways, but sometimes both basins and hills are very gently inclined, so that the whole constitutes a broad and steep ridge. The moraine is traversed here and there by valleys through which water escaped from the ice sheet. These may be of very small size or many miles in width, and may cut down to the bedrock below.

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advanced further southwest, but did not rest at any one point long enough to deposit a moraine. Instead along the line of the first member until that moraine had accumulated and the drainage channel numbered 2 on the map had been formed. The ice then receded, as has already been sketched under the heading "Ancient channels and terraces." Subsequently the ice passed in its retreat, and then, after forming a slight moraine south of Havon and nearly north of the State, receded so far that it no longer influenced this area. The streams by this time had become fixed in their present courses, and though probably somewhat larger than at present, had little effect on the surface of the country except to deepen channels that were previously occupied by water. It is believed that James River had cut nearly to its present depth before the ice disappeared from the State.

The principal geological event since the disappearance of the ice sheet has been the deposition of the thin mantle constituting soil. This has gone on by the formation of alluvium along the principal streams, by the wash from hillsides, and by the settling of dust from the atmosphere. Those soil-making agencies may be added the burrowing of animals, by which the soil is loosened, and the deposition of vegetable remains.

**ECONOMIC GEOLOGY.**

In this area there are no deposits of mineral ores or coal. The few samples of mineral that are sometimes submitted to geologists for examination are invariably iron pyrites, which have no value unless found in very large quantities. Fragments of coal are sometimes found in the drift, but those were brought by the ice or by streams from the lignite beds of the northern part of James River Valley, in North Dakota.

**BUILDING STONE.**

Most of the stone that has been used for foundations and other rough building has been derived from the drift. It consists of limestones and greenstones.

**Sandstone.** The brown sandstone of the upper Benton has been locally used for rough work. It has been quarried on Firesteel Creek near the railroad crossing. At that point the stone is durable and blocks of considerable size may be cut, although the stone is not of fine enough texture for good work. It is very hard and the stone of equal excellence is found in exposures in sec. 34 and 35, T. 104, R. 61, and also in sec. 22, T. 104, R. 60. At the other points marked on the map it seems to be too soft for use in permanent buildings.

**Clay.** There are no lodes of limonite in the region, but chalkstone has been used for the walls of buildings, especially in early years, and several building blocks in Mitchell show its partial appearance and durability. The stone, when carefully chosen and burned, seems to be most durable. It may be cut with a common saw, but stands the weathering so well that not many blocks of considerable size remain and the danger of injury in quarrying. It has a hardness and presents the qualities common to surficial clays.

**Rocks and gravel.**

Along channels occupied during the Glacial epoch deposits of sand and gravel abound at several points, so far as can be judged from watercourse appearances. Pits have been opened on the edge of a high terrace northeast of Mitchell, adjoining the town, also along the old channel north of Mount Vernon, and in the bottom of the channel near the southeast corner of sec. 30, T. 105, R. 62 (Mount Vernon Township).

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**Figure 9. Sketch map of Mitchell quadrangle showing approximate clepths to the bottom of the drift. Water can usually be obtained from sands and gravel at the base of the drift, and generally rises many feet in wells.**

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SHALLOW WELLS.

By shallow wells is meant those supplies from water that have recently settled on the surface and that can be obtained without penetrating an impermeable layer. Wells of this class can easily obtain water close to any of the present watercourses, or near the bottom of a large depression or near a channel draining a considerable area. The reason for this is obvious, since the water comes from precipitation only and the region is subject to continuous drainage. Only those wells of this class that are so situated as to draw from a large catchment basin can be depended upon for a permanent supply. In digging such wells, if no water is reached before the blue-bollar clay is struck, none will be found until the clay has been passed through.

TUBULAR WELLS.

Under this head will be included simply the deep wells in which a tubular or flume pipe is usually necessary. Frequently the water rises near to the surface, and occasionally it flows. These wells are from 100 to 200 feet deep. In this region the deep tubular wells usually derive their waters from the upper sandstone of the Benton formation, but a few obtain water from the sands underneath the till, and some from the chalk just beneath. Others possibly derive water from the lower part of the chalk formation, although this case is not well proved.

The wells supplied from the sands below the till are mainly in the southern part of this region, although there are a few in the northwest and in the north which possibly may be supplied from this source. The depth to the base of the till is shown in fig. 9. The reason water is not commonly found at this horizon, as in other regions, is seen in the prominence of the underlying clay and the deep channels which traverse it. As a result of these, not only are sands below the till less common, but their waters when present look out at the surface. A few wells in the vicinity of Plunkinton, in a district extending a strip north and south, appear to be supplied from the lower part of the chalk. They are reported to furnish hard water, and some of them give forth a disagreeable odor. That water is sometimes derived from the chalkstone is indicated by the fact that some of these wells are shallower than those which supply water from the sandstone in the same localities, as well as by the fact that water is found in the lower portion of the chalk in the quadrangle next east. It is not known, however, whether this water has found its way down from the surface or whether it has passed upward from the underlying sands and become contaminated with lime or sulphurated hydrogen from the chalkstone and shale.

A very important and valuable supply of water is derived from the first sandstone below the chalk, which has been erroneously called the first sandstone of the Dakota, and is seen on the Artesian Geology sheet. Throughout the whole quadrangle this water is hard and is frequently spoken of as "as hard as water." It is not pure, but carries considerable quantities of soluble alkali, which, however, does not impair its use. Unlike the waters from lower levels, it does not rust iron and tin, and it may be used for washing without the use of any alkali to "break it." It is the favorite supply of pump wells, and many draw from this source who have a copious supply of artesian water. The water from this sandstone may be obtained at the highest levels of the southeastern part of the quadrangle at a depth of less than 300 feet—near Plunkinton, 200 feet; and north of Mitchell, 150 feet—and in the central and southeastern portions of the quadrangle at a depth of about 400 feet. Such is the case near Arland, as a standard, that there are the water-bearing beds mainly in sheet form but that they rise as the chalk, or the uppermost portions of the underlying quartzite and overlap, yet each sandstone probably ends at a certain level, though originally corresponded to that of the shore at the time the sand was deposited; hence the lower beds do not extend so far as the upper, and are more closely approximated near the margin. It is not impossible that, by the interpretation of certain existing wells, evidence may be found showing that different water-bearing sandstones communicate imperfectly with one another along the surface contact of the quartzite.

Following this interpretation, it is concluded, taking the Storla well in sec. 35, T. 106, R. 63 (Belford Township) as a standard, that there are represented, first, the top-sandstone of the Benton formation, with its soft water, at a depth of 130 feet, which is called water-bearing horizon No. 1; another at 470 feet, which is commonly the first flow, here called water-bearing horizon No. 2; one at 535 feet, which is No. 3; at 620 feet No. 4; and at 740 feet No. 5. Probably some of these are local and not continuous to this other. This horizon No. 1 supplies the soft-water artesian wells north of Firesteel Creek, except those already mentioned as belonging to No. 1; also the so-called first flow in Badger Township, and most of those around Mount Vernon.

Water-bearing horizon No. 2 corresponds to what has usually been called the second flow, and is that which has been here taken as the general flow, whose pressure is indicated on the Artesian Water sheet. This horizon, it is believed, supplies the flow of the Kilhorn well, in sec. 23, T. 104, R. 62; the Schlimm well, in the next section south; and the second flow in the J. K. Johnson well and the Arland well, both in Mount Vernon Township; and the Cook, Daugan, and Arland wells of the Viola Township (T. 104, R. 63). A number of deeper wells further south derive water from the same horizon. Water-bearing horizon No. 4, it is believed, is represented in the Woodward well, in sec. 23, Lecher Township, in the J. K. Johnson well, and in the Barlow, Plunkinton, and other wells in that vicinity. The apparent discrepancy in depth to flow in several of these wells is explained by the fact that the second and third water-bearing horizons are allowed to flow together in the wells. It is stated that the pressure in water-bearing horizon No. 4 was about 90 pounds at first, and the water from horizon No. 5 has a pressure of 55 pounds. The fifth water-bearing horizon of the Storla well and the Boe well, in the Cook Township, is probably represented by the fourth in some of the other deep wells, and this fifth water-bearing horizon is said to extend to the side of this ridge. It may possibly be found underlying the northwest corner of the quadrangle, coming in on the south side of this ridge.

It has been remarked that water-bearing sandstone No. 2 is supplied with water not from Firesteel Creek on the north. Water-bearing sandstone No. 3 supplies soft water in the Barick and Jacobson wells, northwest and northeast of Letcher. This peculiar distribution of soft water toward the north and hard water toward the south is rather difficult to explain. Doubtless it is accounted for by the water percolating through the sandstone and finally ending in the water-bearing chalk. In the relative copiousness of their supply. Compare the difference in composition in the inclusion of the water-bearing bed may possibly be found in the large deposition of lime and iron oxides near the shore, while more soluble compounds are accumulated in the deeper portions of the bed. A second Arm—Artesian wells vary much in composition and relative copiousness of their supply. Compared with the large wells those of small diameter afford a much smaller supply than the difference in composition in the quadrangle. In all these cases the water that is derived from the sandstone is indicated by the fact that the waters which have imperfect casing or connections, allow water to escape beneath the surface, so that the full force is not shown at the mouth of the well. From the different pressures in different wells and from water from different flows and formations underlying portions of the same sandstone in the same locality, it is evident that there are, as before stated, several water-bearing beds in the Dakota formation underlying portions of the depth in the quadrangle. The lower ones appear to exist only in the northern and western portions, but the upper ones are of wide extent.
water from the second water-bearing sandstone afforded only a flow from a 2-inch pipe, and yet the obsession run up to 30 or even 50 pounds, while others in the vicinity deriving their supply from the third water-bearing sandstone afforded several hundred barrels a day with less than half the pressure. The primary cause, therefore, of the amount of the discharge must be found in the peculiarity of the water-bearing strata and the perfection with which the well is kept in communication with the stratum. From this it may be understood 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 amount of water in the water-bearing rock. This latter factor is the cause of the effect, which maintains the bottom of the well; hence a well that strikes the thin portion of the water-bearing bed cannot obtain so great a flow as one penetrating a thicker portion, other things being equal.

Wells in this quadrangle that are 2 inches in diameter, which is a very common size, vary in the amount of their flow from less than a gallon a minute to more than 200 gallons. Wells extending in the direction of the ridges and those that have large diameters, and for that reason and because of the higher pressure of the water in the lower zones, as well as because the thickness of the lower strata, their discharge is much greater. One of the largest flows is from a well north of Mitchell belonging to J. K. Johnson. It is estimated to furnish 700 gallons a minute from a pipe having a diameter of 41 inches. Another is the Plankinton well, with a flow of 250 gallons and a diameter at the bottom of 3 inches. Without doubt, however, the largest flow is from the Kibb. en well. With a diameter at the bottom of 3 inches, it is 700 gallons a minute from a pipe charged pipes, one 4i and the other 3 inches in diameter, constantly full. No careful estimate has been made of the amount discharged, but it must approach if not surpass 1000 gallons a minute. This is from a depth of only 200 feet, but it is believed to belong to the third water-bearing bed.

Quality of water.—Alluvial has already been made in the analysis of water in the Beaton sandstones and in the lower sandstones toward the south. In all these cases the water has a pleasant taste, many having the impression that it is quite pure, but evaporation shows that it is impregnated with some white mineral, probably carbonate of lime. It may be that the delivering up takes place rather easily as rain water. It does not rust iron and does not clog the iron pipes as does surface water. The iron pipe is generally left in the wells that is common to other arid regions.

The waters from the second and third water-bearing sandstones toward the south and from the fourth and fifth horizons throughout the quadrangle are headwater. They deposit a coating of rust on all objects with which they come in contact; moreover, they rapidly corrode the iron pipes used in the wells. This latter difficulty is to some extent obviated somewhat by the use of galvanized pipes, but even that in time yields at the joints, where the rust is removed. It is the common impression that ordinary iron pipes are destroyed in less than ten years.

Forcing pressure.—In general the pressure increases with the depth in different sandstones.

This is true mainly because there is less chance for backsgaps along their eastern margin, 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 shallowest water-bearing sandstones, including in most cases, there are some marked exceptions. Perhaps the most notable is that already alluded to west and south of Latchert, where the second water-bearing bed has a considerably higher pressure and much more rapid slope of pressure toward the southeast than are found in the next water-bearing bed below. This seems probable, from some facts noticed in wells in the southern part of the quadrangle, that the lowest water-bearing bed has not the pressure of some higher up. This may be connected with the fact that several deep wells have been sunk in Douglas County, which perhaps have locally diminished the water from this stratum more than from those higher up.

Cause of apparent decline in pressure.—It is a fact now generally admitted that not only does the flow of wells decrease, but their first pressure declines. This again is very 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 gap shows that this is merely a decline in the amount of flow, without material decline in pressure, but in many cases the pressure is also found to be markedly diminished.

For example, at Mitchell the water at first rose 15 feet above the well, and in a few days, it fell to 8 feet. This latter difficulty is particularly evident without direct determinations. A test which is similar to the above, might be made in the following way. This would be first to fill a pipe with water, and then to observe whether or not the flow continues. In a test of this kind, with the gap, it is shown that the water is thrown from a horizontal pipe, and that it now barely reaches the ground. In view of such a possibility of overtaxing the supply, it would seem desirable to limit in some way the number of large wells 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 250 barrels a day, or 7 gallons per minute, which would be a sufficient supply for any ordinary farm. As it is, some large wells have been drilled with the intention of irrigating from them, and sufficient rainfall during recent years has rendered them worse than useless, for by their overflow considerable areas have been reduced to unproductive marshes.

BOLIS

No careful analysis of the soils of the region has been made and only some of the more obvious characteristics can be noted here. The soils may be broadly divided into three classes—stony, sandy, and clayey.

Stony soils are represented only in limited areas found mainly on the more abrupt slopes of the prominent moraines and near the old lake beds. These, as described in till-covered areas, large bowlder fields are found mainly on the surface. Along the moraines there are ridges that are stony and gravelly. Along the streams, especially on the abrupt edges of the higher terraces, and sometimes ebbing them for several rods back, bowlder and especially of smaller size, usually abound. They are parts of a horizontal strata originally laid down in the bottom of an ancient channel. This coarse material seldom extends very far back from the edge of the valley or very far up and down the stream. It represents bowlder bars that accumulated at prehistoric times. Some of this material underlying the surface at so shallow a depth that it becomes a serious injury to the soil, because it produces too rapid underdrainage.

Sandy and loamy soils are found in the northern portion of the quadrangle, over both the old lake bed and the platted prairie adjoining. So, also, sand and gravel abound north and east of Mitchell, where the accumulation seems to have been on top of an old terrace and has possibly been increased in quantity by wind action, the sands being derived from the adjacent valley of French Creek.

While the soil of this quadrangle resembles that in other drift-covered regions, there are peculiarities that need further explanation. In the moraine areas the soil varies considerably in short distances. The basins are usually covered with clayey soil, while this is more pronouncedly clayey toward the outer edge, containing bowlder near the margin. The loams of these areas are not only stony, as already described, but contain a great quantity of sand and gravel. The differences are not sufficient to require special treatment. Ordinary tillage so mingles the different soils that they are mutually beneficial.

A very different condition is found on the till— covered surface outside the moraine, especially where the land is unusually level. On the ordinary till-covered areas the surface is more impregnated with clay and more highly weathered. These differ much in size and in depth. In wet weather these areas are very soft and sticky, and in dry weather very hard and frequently sealed with mud cracks. They are usually covered with what is commonly called alkali grass, that in the latter part of the summer is dry, and in the former part of the summer is green. Sometimes the alkali in these spots is so abundant that they become barren. Frequently they are depressed below the level of the ground about them. This may be due partly to the wind blowing against them and partly to the blowing silt of the surrounding bowlder in previous times licking the alkali at one time and outcropping the soil on the other. In a few shallow cases near Plankinton it was noticed that the clay extended horizontally and that it and the loam were somewhat intermixed. This is probably that this peculiar feature of the country is due to bowlder or masses of Cretaceous clay that would have been washed in the ice age, but mingled with the other ingredients of the till. Another and more probable explanation is that alkaline water, gathering in depressions on the surface, dissolved out the silt, or fine quartz sand, in the till, leaving only the clay. These spots, though producing a marked impression on the vegetation of the natural surface, are not found to seriously injure crops, probably a help rather than a hindrance. Where it is collected in a large basin, so as to be persistent at one point in spite of cultivation, drainage, and the addition of armonous manures.

Inside of the moraines, especially in the last country east of Morris Run, irregularities of a different character are found. In that region there are over the surface low knolls and ridges, rarely more than a foot in height, on which bowlder grass grows, while the intervening surface is covered with blue joint. A section shows that the general surface is sandy, while the ridges are clayey. Apparently the knolls are projections of the till, while the sandy areas were deposited in the depressions by water or wind. In some cases a few inches deep is found covering the till surface. Possibly the thick growth of bowlder grass holds the fine dust better than the surrounding grass, and so causes it to accumulate. This Quincy surface is not due to the presence of alkali, and it yields more easily to tillage than those already described.

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