SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 25

# GEOLOGY AND WATER RESOURCES

# of

# DAY COUNTY, SOUTH DAKOTA

by

E. P. Rothrock

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Vermillion, S. Dak.

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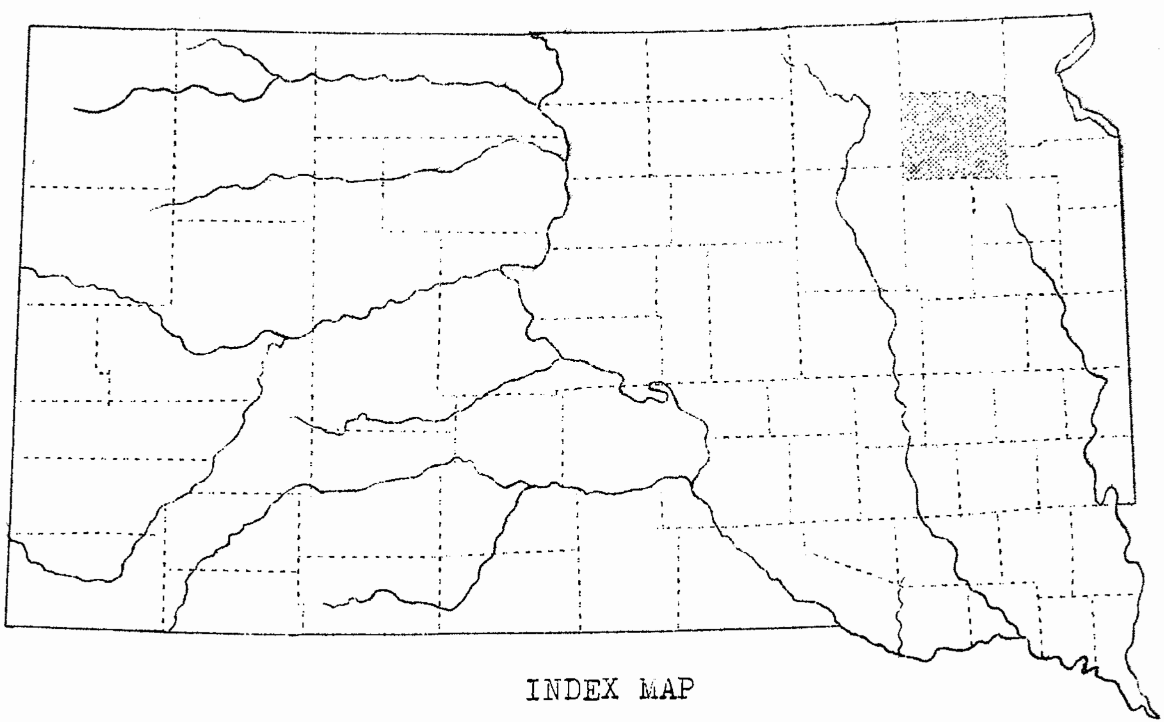


INDEX MAP

Shaded area indicates location of Day County.

# GEOLOGY AND WATER RESOURCES OF DAY COUNTY

## SOUTH DAKOTA

by

E. P. ROTHROCK

## LOCATION AND AREA

Day County is of interest because it is one of the very few counties which lies largely in the region known as the Coteau des Prairies (Prairie Hills) to the old French traders, and because it contains part of the lake region of South Dakota which has long been a popular resort for sportsmen.

It lies in the northeastern part of the state, being but one county removed from North Dakota and one county from Minnesota. In shape it would be a rectangle thirty-eight miles east and west and thirty miles north and south but for a break at the northeast corner, where the northern boundary has been moved southward for two miles due to a difference in location of the surveyed township boundaries in the Sisseton Indian Reservation, which occupies the eastern part of the county, and those of the rest of the county. Natural boundaries such as lakes or streams being absent, the boundaries are all surveyed lines corresponding to township lines of the Jeffersonian land survey of this region. They enclose an area of approximately 1140 square miles.

Within this area lies a most interesting display of geological features. Some can be turned to good account by the residents of the county. It is in the hope that a knowledge of the geological and economic features of the county may lead to a more intelligent use of the resources which it contains and thereby increase proportionately the prosperity and happiness of its citizens, that this investigation is here reported.

## GEOGRAPHIC FEATURES

According to the geographers, the factors which make or break a country as a region for human habitation may be divided into three groups: those having to do with climate, those dealing with access, and those depending on the natural resources.

### Climate

Day County has a characteristic continental climate. It is a climate of extremes, rapid changes from cold to hot, cold winters and hot summers, with rapid changes from hot to cold days at either season. This is the climate of most of the Mississippi Basin, and the differences between the climate in Day County and other parts of the Basin are due to its latitude and slight local variations in its elevation.

The average temperature for the county is shown on the accompanying table, which is the record kept at Webster for the U. S. Weather Bureau. A perusal of the chart shows that the average annual temperature for the time the record has been kept was 42.8° Fahrenheit. The lowest recorded temperature was in 1916, when the record gives 40° below zero Fahrenheit. The hottest day occurred in 1934, when the record showed 108° Fahrenheit in July.

The rainfall record is interesting in that it shows a previous drouth of greater intensity than that through which the country has just passed. The average annual rainfall for the time the record has been kept is 22.17 inches. The highest rainfall recorded was in 1896, when 42.17 inches fell. The lowest recorded was in 1923, with a fall of only 15.38 inches. The use of the region for farming depends more on the time at which rain falls, and the record shows that most of the rain fell in the summer time, June, July, and August having the highest average precipitation. The monthly averages are given as follows:

| | | | |
|---|---|---|---|
| January | .75 | July | 3.13 |
| February | .49 | August | 3.53 |
| March | .92 | September | 2.50 |
| April | 2.00 | October | 1.37 |
| May | 2.65 | November | .74 |
| June | 3.64 | December | .51 |

Total rainfall is of course important from the standpoint of water supply, especially that for the lakes. Their record shows that they have fluctuated greatly and probably in cycles

PRECIPITATION, ANNUAL AND AVERAGE AMOUNTS (IN INCHES AND HUNDREDTHS)

WEBSTER, DAY COUNTY, SOUTH DAKOTA

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1887 | 4.55 | | | | | | | | | | | | |
| 1896 | 1.07 | 3.48 | 1.80 | 8.30 | 4.89 | 6.82 | 3.72 | 3.23 | 2.62 | 2.79 | 2.24 | 1.21 | 42.17 |
| 1897 | 5.69 | | 5.55 | 1.59 | .84 | | | | | | | | |
| 1898 | | | | | | | | | 12 | 1.71 | .35 | | |
| 1899 | .19 | .20 | 2.58 | .82 | 3.61 | 3.85 | .93 | 8.02 | 1.69 | 1.87 | .47 | .29 | 24.52 |
| 1900 | .22 | .45 | 2.10 | 1.47 | .41 | .56 | 4.61 | 4.80 | 7.90 | 1.29 | .22 | .50 | 24.53 |
| 1901 | .10 | .43 | .78 | 1.63 | 1.98 | 5.61 | 2.27 | 2.89 | 7.00 | 1.77 | .08 | .14 | 24.68 |
| 1902 | .25 | .10 | 1.34 | 1.28 | 3.25 | 1.70 | 2.76 | 2.91 | .30 | 2.16 | .49 | 1.15 | 17.69 |
| 1903 | .28 | .15 | .95 | 1.33 | 3.75 | 4.63 | 6.52 | 6.15 | 3.99 | 1.68 | .17 | 1.14 | 30.74 |
| 1904 | | | | | | | | | | | | | |
| 1905 | | | | | | | | | | | | | |
| 1906 | .30 | .15 | 1.15 | 2.46 | 6.10 | 3.52 | 2.39 | 7.33 | 2.39 | 1.36 | 1.01 | .47 | 28.63 |
| 1907 | 1.09 | .58 | .25 | .38 | 1.82 | 3.47 | 2.08 | 4.30 | .68 | 1.26 | .04 | .13 | 16.08 |
| 1908 | .13 | 1.02 | .80 | 2.09 | 2.32 | 3.98 | 1.93 | 3.44 | 1.28 | 2.01 | 1.38 | .47 | 28.63 |
| 1909 | .42 | .16 | .33 | .87 | 2.95 | 1.80 | 2.88 | 3.06 | 2.33 | 2.55 | .80 | 1.74 | 19.89 |
| 1910 | .62 | .86 | .29 | 2.22 | .50 | 4.54 | 1.37 | 5.40 | 1.36 | .89 | .44 | .48 | 18.97 |
| 1911 | .71 | .25 | .03 | 1.50 | 2.85 | 2.91 | 3.61 | 6.09 | 3.40 | 2.25 | 1.05 | .25 | 24.90 |
| 1912 | .12 | .07 | .22 | 7.77 | 1.87 | 2.38 | 4.88 | 2.47 | 2.19 | .04 | | .38 | 22.39 |
| 1913 | .60 | .12 | .32 | 1.35 | 3.94 | 1.28 | 3.38 | 1.87 | 1.47 | 2.59 | .17 | .32 | 17.41 |
| 1914 | .24 | .22 | .67 | 3.04 | 2.51 | 7.82 | 2.84 | 3.34 | 4.75 | 1.06 | | .31 | 26.80 |
| 1915 | .49 | 1.11 | .35 | 1.34 | 4.40 | 6.38 | 2.63 | 1.00 | 4.85 | 1.79 | .50 | .66 | 25.50 |
| 1916 | 1.88 | .12 | 1.34 | 1.88 | 5.36 | 3.84 | 5.02 | 6.37 | 1.72 | .44 | .04 | .90 | 28.91 |
| 1917 | .55 | .32 | 1.47 | 3.47 | .39 | 4.67 | 1.07 | .87 | 2.25 | .20 | .16 | .37 | 15.79 |
| 1918 | .48 | .28 | .51 | 1.63 | 2.26 | 2.47 | 1.93 | 4.79 | | .98 | 1.27 | .83 | 17.43 |
| 1919 | .09 | .50 | .08 | 1.37 | 5.27 | 3.61 | 2.39 | 1.15 | .33 | 1.26 | 1.11 | .18 | 17.34 |
| 1920 | .30 | .34 | .40 | 1.29 | 2.14 | 5.91 | 4.07 | | 2.01 | .37 | .91 | .10 | 17.84 |
| 1921 | .12 | .10 | .90 | 1.01 | 1.29 | 2.55 | 4.92 | 2.31 | 9.99 | .54 | .47 | .05 | 24.25 |
| 1922 | .70 | .90 | 1.17 | 1.99 | 2.18 | .76 | 1.73 | 1.12 | .86 | .66 | 4.39 | .21 | 16.67 |
| 1923 | .72 | .36 | .33 | 1.87 | 3.07 | 3.23 | 2.19 | 1.04 | 1.46 | .39 | .67 | .05 | 15.38 |
| 1924 | .05 | .30 | .86 | 2.66 | 1.47 | 3.62 | 1.78 | 4.48 | 2.19 | .89 | .08 | .83 | 19.21 |
| 1925 | .20 | .25 | .27 | 1.59 | 1.98 | 7.43 | 3.38 | 3.40 | 2.38 | .36 | .66 | .25 | 22.15 |
| 1926 | .60 | .81 | .45 | .52 | 2.32 | 1.17 | 1.37 | 3.54 | | | | | |
| 1927 | .70 | .47 | .90 | 2.82 | 3.87 | 3.47 | 5.50 | 3.87 | 2.35 | .94 | .72 | 1.14 | 26.66 |
| 1928 | .45 | .48 | .33 | 1.11 | .65 | 2.87 | 4.95 | 5.71 | 1.65 | 2.34 | .87 | .44 | 21.85 |
| 1929 | .90 | .55 | .79 | 1.90 | 2.47 | .61 | 5.62 | 1.24 | 2.56 | 1.68 | .40 | .60 | 19.32 |
| 1930 | .60 | .41 | .15 | 1.17 | 2.23 | 4.60 | 2.75 | 2.53 | .29 | 1.25 | 1.32 | .05 | 17.35 |
| 1931 | .15 | .78 | .67 | .95 | 3.96 | 5.28 | 2.88 | 2.92 | 1.21 | 3.08 | .71 | .15 | 22.74 |
| 1932 | .40 | .05 | .33 | 1.63 | 4.30 | 3.17 | 2.16 | 1.64 | .93 | .72 | .44 | .22 | 15.99 |
| 1933 | .21 | .15 | .74 | 1.21 | 2.26 | 3.37 | 3.23 | .91 | 1.58 | | .33 | .62 | 14.81 |
| 1934 | .02 | T | .72 | .15 | .50 | 6.37 | 1.30 | 1.64 | 2.00 | 2.38 | .65 | .18 | 15.91 |
| 1935 | .42 | .43 | 1.68 | 3.75 | 1.13 | 3.17 | 3.77 | 2.58 | | | | | |
| Ave. | .70 | .47 | .90 | 1.98 | 2.62 | 3.70 | 3.07 | 3.38 | 2.50 | 1.39 | .74 | .49 | 21.23 |

WEATHER STATION AT WEBSTER, DAY CO., S. DAK.

TEMPERATURE (DEGREES FAHRENHEIT)

| Year | Highest | Lowest | Annual Mean |
|---|---|---|---|
| 1900 | 99 | -27 | 42.3 |
| 1901 | 100 | -31 | 41.5 |
| 1902 | 96 | -29 | 40.2 |
| 1903 | 90 | | |
| 1904 | | | |
| 1905 | | | |
| 1906 | 94 | | |
| 1907 | 91 | -31 | 39.4 |
| 1908 | 95 | -24 | 42.8 |
| 1909 | 94 | -29 | 40.2 |
| 1910 | 93 | -26 | |
| 1911 | | | |
| 1912 | 94 | -39 | 39.9 |
| 1913 | 99 | -27 | 42.0 |
| 1914 | 95 | -28 | 41.8 |
| 1915 | 85 | -34 | 40.8 |
| 1916 | 93 | -40 | 38.3 |
| 1917 | | | |
| 1918 | 94 | -33 | 41.4 |
| 1919 | 100 | -34 | 40.3 |
| 1920 | | -26 | |
| 1921 | 98 | -22 | |
| 1922 | 98 | -24 | 42.1 |
| 1923 | 94 | -21 | 42.7 |
| 1924 | 92 | -32 | 39.8 |
| 1925 | 97 | -25 | 42.1 |
| 1926 | 104 | -20 | 41.9 |
| 1927 | 93 | -27 | 40.0 |
| 1928 | 94 | -31 | 42.6 |
| 1929 | 94 | -33 | 41.4 |
| 1930 | 100 | -32 | 44.7 |
| 1931 | 105 | -16 | 46.2 |
| 1932 | 103 | -26 | 41.3 |
| 1933 | 104 | -33 | 43.7 |
| 1934 | 108 | -25 | 44.8 |
| Average | | | 41.7 |

FROST DATA

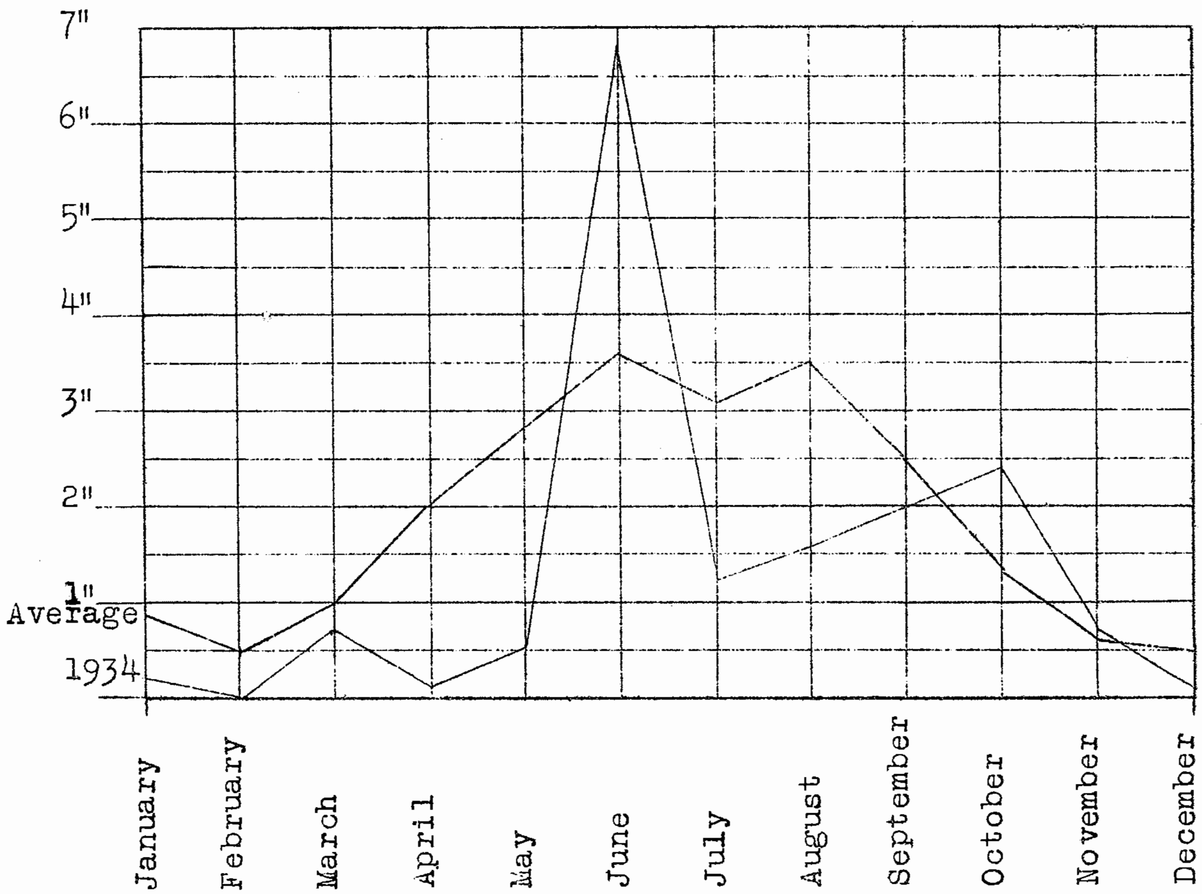
| Year | Last Killing Frost in Spring | First Killing Frost in Autumn | Length Growing Season |
|---|---|---|---|
| 1906 | May 27 | Oct. 5 | 131 |
| 1907 | May 27 | Sept. 30 | 126 |
| 1908 | May 6 | Sept. 28 | 145 |
| 1909 | May 10 | Oct. 11 | 154 |
| 1910 | May 25 | Sept. 9 | 107 |
| 1911 | May 12 | Oct.20 | 161 |
| 1912 | May 13 | Sept. 25 | 135 |
| 1913 | May 19 | Oct. 5 | 139 |
| 1914 | May 13 | Aug. 26 | 105 |
| 1915 | May 19 | Oct. 5 | 139 |
| 1916 | May 11 | Sept. 15 | 127 |
| 1917 | May 22 | Oct. 8 | 139 |
| 1918 | May 12 | Sept. 16 | 127 |
| 1919 | May 5 | Sept. 25 | 143 |
| 1920 | Apr. 30 | Sept. 30 | 153 |
| 1921 | May 15 | Oct. 3 | 141 |
| 1922 | Apr. 19 | Sept. 10 | 144 |
| 1923 | May 12 | Sept. 13 | 124 |
| 1924 | May 25 | Nov. 2 | 161 |
| 1925 | May 17 | Sept. 21 | 127 |
| 1926 | May 22 | Sept. 24 | 125 |
| 1927 | May 5 | Sept. 20 | 138 |
| 1928 | May 27 | Sept. 23 | 119 |
| 1929 | May 20 | Sept. 6 | 109 |
| 1930 | May 17 | Sept. 20 | 126 |
| 1931 | May 22 | Oct. 8 | 139 |
| 1932 | May 1 | Sept. 20 | 142 |
| 1933 | Apr. 27 | Oct. 7 | 163 |
| 1934 | May 25 | Sept. 21 | |
| Average | | | 126 |

Latest date of killing frost in Spring----May 27
Earliest date of killing frost in Autumn----Sept. 6

GRAPH SHOWING AVERAGE

ANNUAL AND 1934 RAINFALL IN

DAY COUNTY, SOUTH DAKOTA



corresponding to the cycles of rainfall. Their record is presented elsewhere in this report.

By way of summary it may be said that the climate of Day County is one in which human beings can live and work most happily. It is healthful and invigorating and has sufficient moisture for successful farming in all but a very few years which have occurred at long intervals. Except for a few hot days the summers are pleasantly cool, and the winters are usually temperate with one or two cold snaps which add variety.

## Access

The second geologic factor, access, is especially important to this county since on it depends its ability to market its products. The county cannot be self-sustaining because of its lack of fuels and its emphasis on grain farming. Travel is remarkably easy through and across the county even though it is typically a hilly country. As will be shown later, the rough and impassible parts of the county are interspersed with areas of flat or gently rolling surface over which roads and railroads can be built with ease. The hilly portions lie in belts and are not sufficiently rugged to prevent the building of trunk roads and railroads across them.

Day County's chief outlet is along the Chicago, Milwaukee, St. Paul & Pacific Railroad, whose main line crosses east and west through its center. This line gives rapid and easy access to Aberdeen and Seattle to the west, and to Minneapolis and Chicago to the east. Spurs from the main line of this railroad give outlets north and south. One spur leaves the main line at Andover for points in North Dakota. A second spur leaving the main line at Bristol and running through Butler and Lily, gives an outlet to Sioux Falls.

The Soo Line touches the northeastern part of the county with a line that reaches Grenville and Roslyn, giving an outlet northward to roads into Minneapolis and St. Paul.

Two State highways and an excellent net of county highways give easy access to all parts of the county and to points outside. These highways lead directly to Watertown and Aberdeen as well as to all other cities in this and neighboring states. There is no lack of outlet for the products of Day County.

## Resources

The resources of the county will be discussed under various heads in other parts of this report. They include soils, mineral products, and water supplies. The most important at present and probably in the future is the soil which has made possible the chief industry of the county.

The entire county is covered with glacial drift, and on this material a prairie soil has developed to depths of two or three feet. Being a product of recent glaciation, these soils are very fertile. The rock flour of which the drifts are made has suffered but little leaching and therefore still contains the mineral matter necessary for plant growth in easily soluble form. Most of the surface of the county can be farmed, though there are portions which are too stony or too hilly for this purpose. Considerable areas of swamp, slough land, and lakes also occur which can not normally be used. During the recent drouth, however, these lowlands have been valuable as farm lands and have furnished considerable hay and forage at times when it was sorely needed.

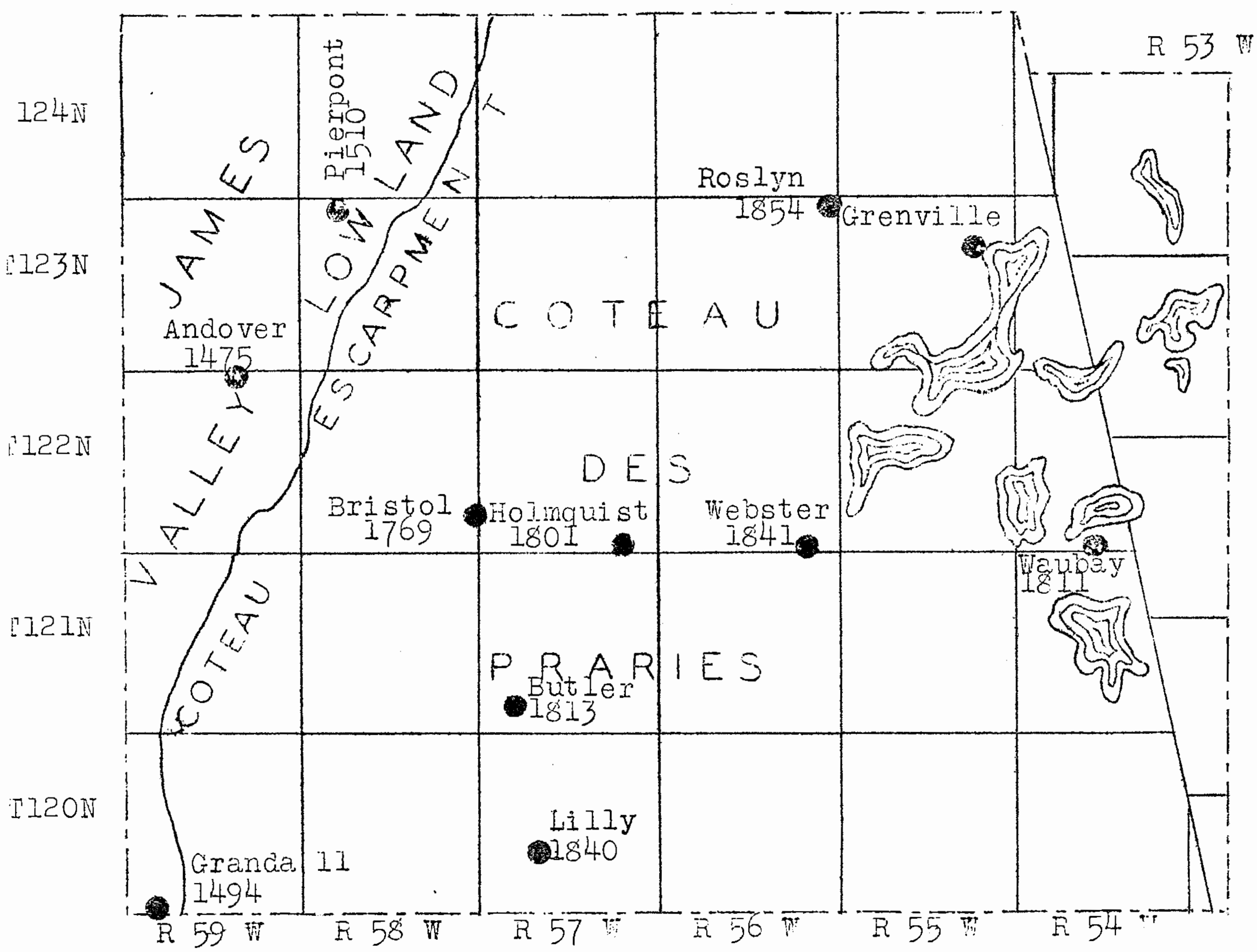
Most of the soils are loams, the heavier ones being developed on the boulder clay of the glacial drift. Lighter soils varying from sandy loams to sands have developed on the outwashes shown on the accompanying glacial map and along the lowland at the base of the western edge of the county. These last comprise a minor part of the soils; probably not more than one hundred square miles of the county would fall in this class. Heavy clay soils are also rare. They were noted in some water channels in which glacial waters had washed quantities of heavy muds. One such occurs in the northwestern corner of the county and covers a few square miles only. The channels of this sort found in the rest of the county are so small as to be insignificant. Most lake bottoms show a sandy muck when the water has dried.

A complete discussion of the soils of Day County is not within the province of a geological report, and with the above generalizations the matter will be left.

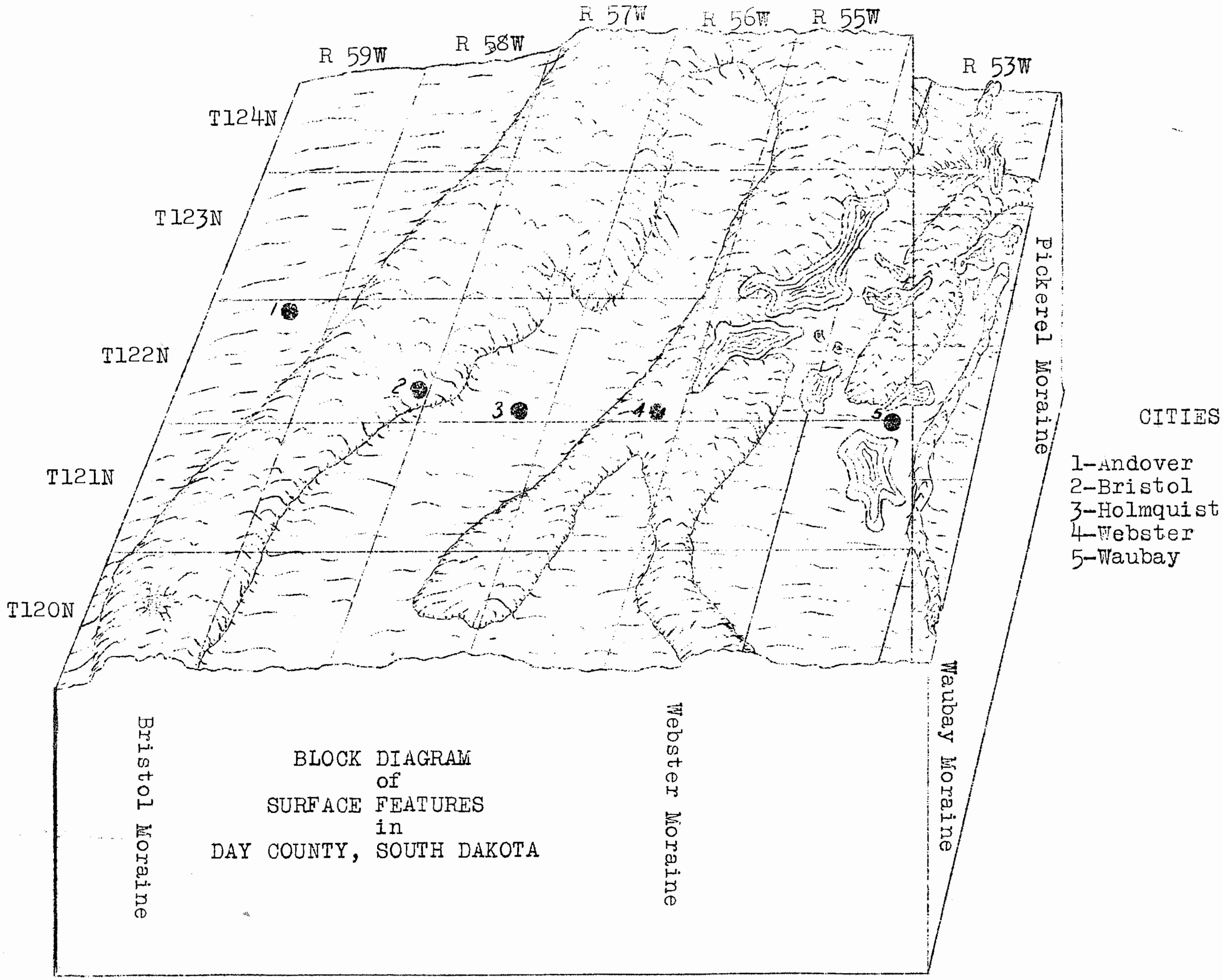
From a geographic standpoint, the lakes of Day County form an important and undeveloped resource. They possess the beauty of expansive wooded shores, sand beaches, fishing and hunting in season, and boating, which supply all that could be asked of an inland body of water by the sportsman and summer vacationist. The ease with which they can be reached either by rail or over excellent highways makes them an expecially attractive feature to those who can make only weekend visits or short vacation trips. Pickerel Lake, Enemy Swim, and Blue Dog Lake are the ones which have been most popular, probably because they are the deepest and have been least affected by drouths. Spring Lake, Minnewasta, and the Waubay Lakes make a group which can be a most important asset to the county. They have competition from the lakes of Wisconsin and Minnesota for the eastern trade but should draw largely from our own state and nearby cities of Minnesota and North Dakota whose citizens seek relief from summer heat or the relaxation of a fall hunting or fishing trip.

PHYSIOGRAPHIC DIVISIONS OF

DAY COUNTY
SOUTH DAKOTA




Figures represent
approximate sea level elevations




BLOCK DIAGRAM
of
SURFACE FEATURES
in
DAY COUNTY, SOUTH DAKOTA

The county possesses an abundance of structural material, largely in the form of sand and gravel. It also contains clays which might be turned to advantage. Its abundant supply of good water is an asset which is usually taken too much for granted. These mineral resources will be described in greater detail under the head of Economic Geology in a latter part of this report.

## TOPOGRAPHY

### The Coteau des Prairies

The surface of Day County can readily be divided into two sections, a highland, the Coteau des Prairies, which occupies the eastern five sixths of the county, and a lowland, the James Valley Lowland, which occupies the extreme western sixth. The highland is part of the Coteau des Prairies, an A-shaped upland which separates the valleys of the Minnesota and James Rivers. Its average elevation in Day County is approximately 1850 feet above sea level. Points on it have been measured which have elevations of more than 1900 feet, while other points have elevations only a little above 1700.

The western edge of the Coteau is marked by an abrupt descent or escarpment about three hundred feet in height which separates the highland from the lowlands of the James Valley. This western escarpment was not generally recognized by the early writers on the Coteau. This omission may have been due to the fact that the early explorers approached the Coteau from the east where the escarpment separating the upland from the Minnesota River valley forms a striking topographic feature as viewed from those lowlands. In 1881, however, Dr. T. C. Chamberlain described the Coteau as follows: "The Coteau des Prairie, the most prominent feature of the region, consists of an A-shaped plateau, the apex of which lies about forty miles west of Lake Traverse and attains a maximum elevation of a little over 2000 above the sea level. This promontory stands boldly forth 600 to 800 feet above the plains which skirt it on the east, north, and west. From this apex the eastern area stretches away south-southeasterly, broadening and flattening until it imperceptibly dies away in southwestern Minnesota. The western branch bears southerly, presenting an abrupt westerly face for more than 100 miles, beyond which it grades down into the undulatory plains of Southeastern Dakota. The Sioux Valley lies between the arms of this topographical A, though its depression is not equal to that of the greater valleys on the exterior"[1]

1. Chamberlain, T. C., U. S. G. S. Third Annual Report, page 390, 1881-82.

East of Pierpont the escarpment rises more than 260 feet above the James Valley Lowland to an elevation of 1960 feet in a distance of three miles. In the southwestern part of the county near Crandall it rises almost like a cliff for 320 feet to an elevation of more than 1800 feet. This escarpment acts as a wall from whose base the lowland stretches away to the west until lost in the hazy distance. At the northern boundary it is twelve miles from the county's northwestern corner, and at its southern boundary it is but two miles from the southwestern corner.

The surface of the upland well deserves the name Coteau (hill country), for the one thing that characterizes its surface is hills. Large rolling hills alternate with gently undulating topography. Four well defined belts of extremely rough, hummocky topography made of boulder-covered hills and kettle-like depressions, so close together that roads avoid them as much as possible, across the upland. These hilly belts are the result of glacial action in which clays, boulders, and other debris carried by the glacial ice was deposited over the country unevenly as the ice melted. Where this deposition took place for a longer time than usual, a ridge of very rough country was formed. These ridges are called terminal moraines in geological parlance.

The four belts of rough terminal moraine run in a more or less north-south direction paralleling the great escarpment at the western edge of the Coteau and are separated from each other by areas of smooth or ground moraine. For purposes of description in this report they will be designated as follows:

1. The Waubay Moraine:- A morainic ridge rising sharply above its surroundings both to the east and the west, crested with extremely rough topography and extremely bouldery hills. This moraine is only about a mile wide and lies east of Bitter Lake and Blue Dog Lake and on the east side of Enemy Swim Lake. The city of Waubay lies a mile west of it.

2. The Pickerel Moraine:- A belt of very rough topography three miles in width that enters Day County from Roberts County east of Pickerel Lake, forms a semicircle about the northern end of Enemy Swim Lake, enclosing the southern end of Pickerel Lake, and is finally lost between Blue Dog and Rush Lakes. The northern end of this moraine is unusually rough and rises to elevations above 1900 feet between Enemy Swim and Pickerel Lakes. The southern end is considerably smoother but still shows the characteristics of terminal topography.

3. The Webster Moraine:- A broad belt of rough topography which reaches a width of six miles along U. S. Highway 12. Its surface is not so rough as the surface of those just mentioned, but large hills and a relief of about 75 feet are characteristic. The moraine enters from Marshall County, trends southeast, and splits into two forks just south of the city of Webster. One fork trends southeast into Codington County, while the other, heading southwest, becomes lost in a low lake county east of Lily and Butler. At its northern end it spreads westward and joins the Bristol Moraine in Liberty township (T.124 N., R. 56 W.).

4. The Bristol Moraine:- The widest of the four morainic belts. It is widest in the northern part of the county, where it reaches widths of ten miles. Its narrowest parts are in the southern part of the county and in some places do not exceed six miles. This moraine lies along the great western escarpment of the Coteau des Prairies. Its western edge lies far down the escarpment at the north but forms the crest and steep face at the southern end. Throughout its length it is very rough and in places is almost impassable to roads. These portions of the moraine are specially noticeable along its western side. Its eastern side usually presents bold hills and wide kettles which grade into the smooth moraine between it and the Webster Moraine. At the north it connects with the Webster Moraine as stated above.

5. Unnamed:- Three miles of a very sharp morainic ridge extending directly north from Pickerel Lake lies in the County. This ridge is but a half mile wide but is a prominent topographic feature in the township in which it lies. It does not seem to be related to the moraines described above but probably belongs to a larger moraine in Roberts County. As there is no detailed information on the morainic system of that county, this ridge will have to await further classification.

Between the belts of hill country just described lie the areas of smooth undulating country which differ so markedly from the hilly country of the terminal moraines. The relief is so slight that it is possible to look across several miles of plain in many places, and some small areas are as flat as the proverbial floor. Reliefs of ten or twenty feet to the mile are the rule. The areas covered by these smooth moraines occupy less than half the area of the Coteau section of the county.

No description of the topography would be complete without mention of the lakes of the Coteau. Lake basins abound in the moraines, but only the deeper ones contained water during the dry summer of 1934. The group of lakes in the eastern part of the county contained water throughout this summer. Though the shallowest were going dry by the last of August, they still deserved the names of lakes. A group of lake basins of nearly equal area lies in the center of the county east of Lily, trending in a rough alinement northward, and ending in shallow basins northwest of Webster. These lake basins are usually designated as sloughs by the residents of that part of the county. Old beaches and other shore indications, however, show that these basins have at some time held water to depths of many feet over a period of years and were just as truly lakes as those which are now holding water. The deepest water, as nearly as could be determined, occurred about 1918, at which time most of these lakes held their maximum of water.

This chain of depressions seems to have been connected with a chain in Codington County, and lies in a large depression which enters the Big Sioux Valley at Lake Kampeska. The lowest elevation on the Coteau was recorded in the basin of the large lake east of Lily. The highway here has a sea level elevation of 1755, while the lake floor at the base of the grade is six to eight feet lower.

## The James Valley Lowland

About one sixth of the county lies in the James Valley Lowland. The surface of this lowland is the direct antithesis of that of the Coteau. It is a plains country. No large hills or valleys break its flat surface, and the general impression on the beholder is the same as that one gets on looking across the limitless expanse of the ocean.

This plain topography begins at an elevation of about 1550 feet at the base of the Coteau Escarpment and from this level slopes gently toward the northwest at a rate of about 35 or 40 feet to the mile. The lowest point in the county, therefore, is in the northwest corner where the elevation is about 1280 or 1300 feet.

The higher parts of the plain are out by a few sharp valleys which reach depths of 40 feet only to flatten out into channels of such slight depths that there is no valley at all three or four miles farther downstream. One such valley lies between Pierpont and Andover, a second two miles north of Pierpont, and a third four miles south of Andover.

These are the largest features of the plain, the rest of the surface being either perfectly flat and featureless or gently rolling like that of the smooth moraines of the Coteau but with a relief not exceeding ten or fifteen feet in a mile. Most of the flat areas are the surfaces of rather indefinite drainage channels through which glacial waters flowed. The undulating portions are surfaces caused by the deposition of glacial drift. Though of the same origin as the smooth moraines of the Coteau, the appearance is very different due to the extremely low relief of the glacial surface. The low hills do not spoil the impression of a lowland plain, and flatness is the prevailing characteristic of the lowland.

## GEOLOGY

### The Bedrock

The geology of Day County divides itself into two sets of phenomena, one pertaining to the bedrock, or foundation of solid rock on which the county rests, and the other to the great pile of glacial debris consisting of loose clays, sands, and gravels which lie on this foundation.

Bedrock is visible in only a few places, and these are confined to the James Valley Lowland immediately in front of the base of the great western escarpment of the Coteau des Prairies. At these places the streams have cut small gorges about fifty feet deep, skimming off the thin mantle of glacial debris and exposing the underlying bedrock. Six outcrops were discovered lying roughly in a straight line which diagonals the northwestern corner of the county, passing through Pierpont and Andover. Three of them lie northeast of Pierpont, two between Pierpont and Andover, and one three miles southwest of Andover. The location of these outcrops is shown on the accompanying geologic map.

In these outcrops a fissile shale is exposed which weathers into flakes much as do the siliceous shales of the Agency Member of the Pierre in the Missouri Valley and the Mowry Member of the Graneros Formation in western South Dakota and in the northern Rocky Mountain region. Bentonite, a white clay of volcanic origin, was exposed in one or two outcrops and also iron concretions carrying minor amounts of manganese.

The following sections will set forth the details of the individual outcrops.

## Shale Outcrop

One quarter mile south of NE. Cor. Sec. 9, T. 124 N., R.58 W.
In roadcut and undercut stream bank 500 feet off road.

5 ft. Gravel; not well exposed; poorly sorted.

8 ft. Shale; dark brown to black; fissile; weathers into flakes. Iron concretions and concretionary layers containing some maganese are abundant, especially near top.

1 ft. Bentonite zone; details as follows:

1/4 in. bentonite
4 in. black shale
1/4 in. bentonite
6 in. black shale
1/4 in. bentonite

5 ft. Black shale like above

12 ft. Black shale exposed in stream cut 500 feet west of road.

## Shale Outcrop

SW$\frac{1}{4}$ Sec. 29, T. 124 N., R. 58 W.
South bluff of small creek $1\frac{1}{2}$ miles north of Pierpont
Highway 25

10 ft. Buff till, massive except for one yellow lens 50 ft. long which has chalk in it. Ordinary run of igneous and metamorphic boulders, one three feet in diameter. Limestone boulders and a few of chalk containing Niobrara oysters.

7 ft. Sand and gravel in 6 inch to 1 ft. beds which are quite distinct and fairly well sorted. Sands are clean, but the gravels contain considerable clay and shale. Some beds are made of shale pieces more or less mixed with pebbles and partly cemented with iron. This corresponds exactly with the driller's description of the 400 ft. water sand on the Coteau, i. e., "alternating streaks of shale and sand." Three or four such zones 6 to 24 inches thick show in this section.

15 ft. Shale; weathers into flakes brown when fresh, gray when dry. Two bentonite streaks five feet above the base of the section.
1/2 in. bentonite
6-12 in. shale
2 in. bentonite

20 ft. Covered; shale chunks in a slump.

Shale Outcrop

SW¼ Sec. 13, T. 123 N., R. 59 W.
Approximate sea level elevation of top of shale, 1457 feet

1 1/2 ft. Loess-like soil; black on top, grading into brown below, columnar joinings strong; occasional pebbles,

12 ft. Glacial till, dark buff when fresh, and when dry, tan.

10 ft. Sand with 1 to 2 ft. of medium to fine grained gravel at the base.

16 ft. Shale, dark brown when wet, silvery gray when dry; weathers into thin flakes. No fossils unless miscroscopic.

6 ft. Covered; probably same shale as above.

Shale Outcrop

1.9 miles north of Andover
NW¼ Sec. 26, T.123 N.,R.59 W.
North bluff of small canyon
Approximate sea level elevation of top of shale, 1436 ft.

15 ft. Till.

5 ft. Water laid glacial material in fairly well sorted beds of medium to coarse gravel and silt. Not far from the road this section reads:
3 ft. gravel
7 ft. silt
10 ft. gravel

5 ft. Shale, dark gray when fresh, light gray when dry. Rocks on outcrop so dry that they stick to the tongue like meerschaum.
No fossils or concretions observed.

## Shale Outcrop

SW. Cor. Sec. 20, T. 122, R. 59
Approximate elevation top of shale, 1440 feet.

| | |
|---|---|
| 15 ft. | Glacial drift, coarse gravel at the base. Not well exposed but not more than a foot or two in thickness. Pebbles up to one inch in diameter. Overlying drift is till containing large boulders three to six feet in diameter. |
| 30 ft. | Shale; minor laminations; dark brown when fresh but a silvery gray when weathered; weathers into case-hardened thin flakes one half to one inch and smaller. This is a conspicuous character. There is some tendency for this shale to make laminations like the shale in the "fish-scale zone" along the lower Missouri Valley. Fossils absent. Concretionary layers one inch thick occur, usually of black or yellow limonite. |

The lack of fossils in these outcrops makes it impossible to correlate them accurately with the shales known to occur in other parts of the state. The evidence from logs of deep wells suggests that the shale belongs to the Pierre Formation.

The top of the outcrops all lie at approximately the same elevation, indicating that the bedrock surface is essentially a plain. Elevations run from railroad and highway points of known elevation show that the top of the bedrock lies approximately 1440 feet above sea level.

Six miles north of Pierpont outcrops occur in an east-west line which shows the top of the bedrock rising eastward toward the base of the Coteau Escarpment. The total rise, however, is only ninety-seven feet in four miles, which is but a small departure from a plane surface. At Langford, which lies just north of the county line six miles north of Pierpont, the shale surface lies at an elevation of 1340 feet. An outcrop one mile south and one mile east of Langford has an elevation of 1438 feet. A third outcrop one mile east of the second lies at an elevation of 1468 feet, while two miles still further east the last outcrop occurs at an elevation of 1537 feet.

Well data from the highlands of the Coteau is not as definite as that from the outcrops but shows the same tendency. In the vicinity of Roslyn wells penetrate glacial clay to a depth of about four hundred feet. One, about three miles south of the city, struck "shale" at a depth of 410 feet and reports penetrating shale and sand for twenty feet. This is the typical character of the basal sands of the drift. The elevation of the shale at this point, therefore, would be approximately 1450 feet above sea level. A city well at Butler draws water from a glacial sand four hundred feet below the surface. As this probably represents the sand at the contact of the glacial drift and bedrock, the surface of the latter would lie at an elevation of about 1456 feet. Five miles south and one and one half miles east of Webster the shale is encountered at a depth of 502 feet or a sea level elevation of approximately 1360, while in the city of Webster itself, the soft water sand lying approximately at the base of the drift, is encountered at 500 feet, or a sea level elevation of 1466.

Data are too inconclusive to warrant an assumption that the entire surface of the bedrock lies at this particular elevation. The foregoing scattered figures, however, indicate that there is no great variation in the elevation of this surface under most of the county. It presents a plain surface from the outcrops near the western border of the county as far east as Webster and Roslyn, Unfortunately, well data and outcrops were not available for the eastern side of the county, deep drift covering all the bedrock and the abundance of shallow water supplies preventing the necessity of drilling deep wells.

Little is known of the character of the bedrock. Artesian wells have penetrated it to depths of 1550 feet, but the records kept indicate very little concerning the character of its components. The depth of the water sand is noted, but the intervening rocks receive no comment. The most complete record is from an old well drilled by the Chicago, Milwaukee, St. Paul, and Pacific Railroad at Andover. The following log was recorded by the drillers:

Artesian Well at Andover[1]

| Feet | |
|---|---|
| 0-50 | Soil, sand, and clay |
| 50-75 | Blue clay. |
| 75-575 | Blue clay. |
| 575-590 | Limestone. |
| 590-1070 | Shale with streaks of limestone. |
| 1070-1075 | Sandstone with water. |

1. Darton, N. H., Geology and Underground Waters of South Dakota, U. S. G. S. Water Supply Paper No. 227, page 91, 1909.

Since there is no indication of the character of the limestone which is encountered at a depth of 575 feet, it is not possible to tell whether this is chalk from the Niobrara Formation or limestone from the Greenhorn. The abundance of black shale, however, in the section is characteristic of the lower portion of the Cretaceous System in South Dakota.

There is no way at present of knowing what underlies the artesian sand in Day County. Older rocks exposed in the eastern part of Grant County, thirty-six miles to the east, are of granite. West of Day County no wells have been drilled below the artesian flow between Day County and the James River. A well at Aberdeen, sixty miles west, which was reported as having been drilled to granite, reports three hundred feet of rock between the top of the first flow and the granite. Two artesian sandstones are encountered in this interval, one of them lying directly on the granite.[1]

Neither the outcrops to the east nor the deep well to the west throw much light on the rock underlying the artesian sand in Day County since both are too far away. They suggest, however, that other sands lie beneath the one that has been producing artesian water and that "granite" is not far below.

West of the Coteau Escarpment in Day County two sands are known to exist, though only the upper one is used. This latter sand supplies soft, alkaline water which is used for domestic purposes, but cannot be used to irrigate gardens as it ruins the soil. A second flow has been tapped in a few places and is apparently cut off from the upper one entirely, since its water is hard but not alkaline. It can be used for irrigation, but in all places where it has been struck, it has been sealed off because of its undesirable domestic qualities. Near the county line directly west of Pierpont, this sand lies one hundred feet below the top of the first flow. A land owner on whose place five wells were drilled reports the depths as follows:

Record of Artesian Well

$6\frac{1}{2}$ miles east of Pierpont, S. Dak.
$N\frac{1}{4}$ Cor. Sec. 6, T. 123 N., R. 59 W.
Curb elevation, 1316 ft.

| | |
|---|---|
| 0-1070 | Unrecorded |
| 1070-1070 | First flow |
| 1070-1180 | Unrecorded |
| 1180-1180 | Second flow; fine white sand which choked wells so that they had to be abandoned. |

Pressure--sixty-five pounds.

1. Todd, J. E., U. S. G. S. Folio 165 (Aberdeen-Redfield Folio), page 12, 1909.

## Glacial Geology

Resting on the bedrock lies a thick cover of unconsolidated materials deposited by the great ice sheets which covered this part of the state in recent geologic times. Most of it is boulder clay, but mixed with the clay is a great deal of sand and gravel. In the James Valley Lowland this cover is so thin that small streams have uncovered the bedrock in cutting their valleys. Thicknesses of forty or fifty feet of drift were measured in a number of places overlying the exposed bedrock. This is probably an average thickness for the drift in the James Valley Lowland section of Day County, since it was found in so many widely scattered areas. On the Coteaus the drift is much thicker, four hundred to five hundred feet being the average, according to well records. In face the Coteau Highland is a great pile of glacial debris left on top of the bedrock by the retreating ice sheets.

### Materials

The most conspicuous material in the Coteau drift is the boulder clay, geologically known as glacial till. In most outcrops this material is a yellow or tan color, though drillers report blue clay lying beneath the yellow. This clay carries an abundance of boulders, cobbles, and pebbles of various sizes made of very hard rock which the ice sheet picked up in regions farther north. These are inbedded in the clay in a heterogeneous fashion and often mixed with pockets of sand. Boulders several feet in diameter are to be seen, though they are not common, most of them averaging one to two feet in diameter. In some outcrops they make a considerable part of the drift, possibly as much as twenty per cent, but in most exposures they are scattered sparingly through the other materials. They are most conspicuous on the surface in parts of the morainic belts, where they literally cover the ground.

At the base of the clay where it lies on the bedrock there is a very persistent zone of sand and gravels separated by partings of clay which contain flakes of the bedrock shale. So conspicuous is the shale in many of these partings that drillers are accustomed to speak of it as "The shale", though usually qualified by calling it a mixture or alternation of sand and shale. At the bedrock outcrops in the James Valley Lowland these glacial sands and gravels are commonly exposed, but they are not a universal feature of the contact between the shale and the drift. Gravel and sand are to be noted in nearly all sections given above, under the description of the bedrock outcrops. Seventeen feet is the maximum thickness of sand and gravel measured in these exposures. This is probably smaller than the maximum figure which might be obtained from well records, since the sand and gravel of the outcrops were not fully exposed, the overlying boulder clays having crept down the hillside covering much of the sand zone. Wells drilled on the Coteau have not reported more than twenty feet of this sand zone, however.

Other sand pockets and lenses can be encountered in many places in the drift, though there is no way of predicting where they may occur or how large they will be. One such sand, 280 feet beneath the surface at Webster, is sufficiently large to furnish the water supply for the entire city.

Large amounts of sand and gravel lie in sheets and channels on the surface of the boulder clay of the Coteau. The largest of these occur in the lake region, in the eastern part of the county. Particularly notable are the channels from Enemy Swim Lake to Bitter Lake, from Lake Waubay through Rush Lake to Blue Dog Lake, and north of Pickerel Lake. Minor amounts occur along the base of the Coteau Escarpment, while many small patches occur near the crest of the escarpment, as mounds of sand and gravel or underlying small flat areas. There is also a large deposit of sand and gravel occurring as mounds and gravel ridges eight miles south of Webster.

## Origin of the Coteau des Praires

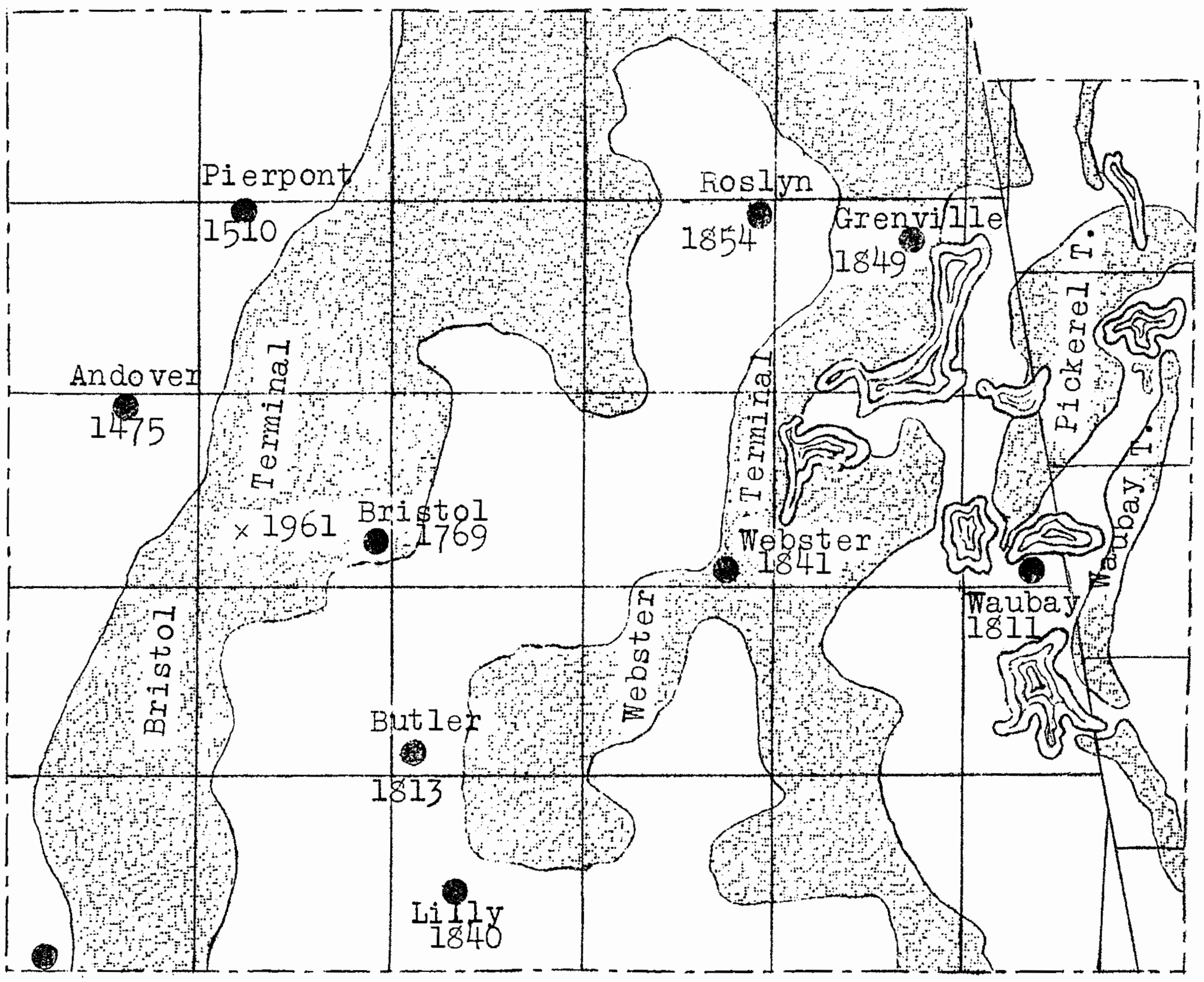
Since the surface features described earlier in this report are all the result of deposition of glacial materials just described, it will not be out of order to explain the glacial geology of the county by describing the origin of the surface features. As has been stated, the Coteau des Praires is a highland composed of glacial drifts. Ice covered parts of eastern South Dakota at least three times during the last great ice age (Pleistocene), and as each ice invasion left, its load of rock debris was strewn over the surface. It is not certain, however, whether the Coteau is the product of drifts left by all these invasions or by only one.

Dr. Frank Leverett studied the Coteau in Minnesota and as far west in South Dakota as the Big Sioux Valley and came to the conclusion that most of the drift was formed by an early ice invasion (Kansan). He states: "The prominent Coteau des Praires in the southwestern part of Minnesota was for some time interpreted by geologists as owing its prominency chiefly to Cretaceous strata, which was thought to fill in gaps between the high areas of Sioux quartzite noted above. But studies by Meinzer along the Coteau and later studies by the present writer have shown that the filling between the quartzite areas consists largely of glacial materials, borings having been put down to depths of four hundred to five hundred feet without encountering rock. The quartzite areas thus seem to stand out above the general level of the bordering Cretaceous formations, much as the Baraboo quartzite of southern Wisconsin stands above the surrounding Paleozoic formations. The highest altitude reached by the Cretaceous of southwestern Minnesota may not exceed 1300 feet. The Coteau surface has an altitude of 1700 to 1900 feet or more along

MORAINES OF THE WISCONSIN ICE SHEET

in

DAY COUNTY, SOUTH DAKOTA




Figures Indicate Approximate

Sea level Elevations at Railroad Stations the highest part of its crest in Minnesota. The morainic ridges of Wisconsin age, which to some extent follow the crest of the Coteau, stand only about fifty feet above the district outside. It thus appears that the great bulk of the glacial material on the Coteau was laid down in earlier stages of glaciation."[1]

No evidence is available in Day County on which to determine the age of the drift forming the Coteau. The only thing that is certain is that four hundred to five hundred feet of drift was deposited on the bedrock to make this high country. Drillers report changes from blue clay to yellow clay in wells, suggesting that there may be two or more drifts beneath this part of the Coteau, but the information on the locations of and persistence of these changes was not sufficient to warrant any generalization. If Dr. Leverett's assumption is right for the eastern side of the Coteau, however, it is more than probable it will also hold true for the western portion, including Day County.

The age of the drift at the surface, however, is certain. No one questions the statement that the drifts which are exposed were left by the last (Wisconsin) ice sheet to visit South Dakota. The absence of streams, the abundance of lakes and swamps, the large amount of lime in the soils, and the possibility of tracing this drift into areas where the drift is known to be Wisconsin, all tell the same story of recent glaciation. During this glaciation two lobes of ice moved from the main ice mass in Canada--one southward across Minnesota, sometimes called the Minnesota lobe, and the other down the James Valley in South Dakota, often known as the Dakota lobe. The Minnesota lobe spread westward until it reached the valley of the present Big Sioux River, while the Dakota lobe spread eastward to the same valley. The Coteau lies at the junction of these two lobes of ice, and into the reentrant thus formed enormous amounts of glacial material were carried by the ice itself and by waters running from its surface.

Day County was covered entirely by the ice from the Dakota lobe, and the surface features, therefore, are the products of this glacier. The ice front advanced to the extreme eastern part of the county, where it halted long enough to pile up a ridge of drift which forms the conspicuous Waubay Moraine which borders the Big Sioux Valley. It lies immediately east of Waubay and can be traced from Enemy Swim Lake southward past Blue Dog and Bitter Lake, leaving the county at its southeast corner.

## Terminal Moraines

Change to a warming climate caused the ice front to retreat from this maximum position. Portions of the ice front would melt rapidly while others held their position, so that instead of a uniform retreat, there was a zig-zag or uneven retreat of various parts of the ice front causing a tangle of morainic belts on the Coteau instead of the continuous and entirely separated ridges

1. Leverett, Frank, Geology of Minnesota and Parts of Adjacent States, U. S. G. S. Prof. Paper 161, page 11.

which are sometimes pictured. A Study of the map, however, shows that the retreat at the south was more rapid than that at the north, so that the ice front appeared to hinge more or less at the northern end of the county.

The Pickerel Moraine represents the second stand of at least a portion of the ice front. The southern end separates Waubay Lake from Enemy Swim and Blue Dog Lakes, the last two of which lie in the outwash of this Moraine. That the northern end represents a long stand of the ice is shown by the extremely rough topography and the fact that it rises to an elevation of 1900 feet. It forms a semi-circle around the northern end of Enemy Swim Lake and apparently surrounds the head of the Big Sioux Valley, merging with the big moraine known as the Altamont Moraine on the east side of that valley.

A third stand of the ice front took a position which includes the Waubay Lakes and retreated very slowly over a belt ten miles wide, forming the Webster Moraine. This moraine is especially rough at the north, but a mile south of the city of Webster splits the two parts evidently representing a more rapid retreat of this southern portion of the ice front.

The last big stand of the ice in Day County is represented by the big moraine which has been designated the Bristol Moraine. It does not have a sharp ridge-like character, but is distinguished by the extremely rough topography over most of its surface. Its western edge forms the crest of the Coteau Escarpment. Its maximum width of ten miles is at the northern end. The width of the southern end averages about five miles. At the northern end, the Bristol Moraine merges with the Webster Moraine, the junction being about five miles northwest of Roslyn.

## Ground Moraines

Ground moraines are smooth surfaced areas lying between the terminal moraines, A rolling surface with relief of twenty to thirty feet or less in a square mile is characteristic. The largest area of this type of moraine in Day County is in the James Valley Lowland, in which the entire surface is a ground moraine.

On the Coteau ground moraines occupy only a third of the surface area. They lie as long narrow strips between the terminal moraines which have been described, the longest one being in front of the Bristol Moraine and extending nearly the entire length of the county. It does not exceed ten miles in width at any point. There are two other ground moraines on the Coteau, one south of Webster in the fork of the Bristol Terminal Moraine and the other east of the Bristol Terminal Moraine between its front and Bitter and Rush Lakes. The first of these is about ten miles north and south by four miles east and west, and the second about fourteen miles north and south by nine or ten miles east and west. Both of these moraines cross the south county line into Codington County, so that only a part of their area lies in Day County.

These ground moraines represent areas over which the ice front retreated without halting and spread its load of debris more evenly than was possible when the front remained stationary or nearly so.

## Outwash

Torrents from the melting ice carried glacial debris with them, sorting the fine from the coarse material and depositing the latter as sand and gravel bodies about the moraines. The Big Sioux Valley received most of the water drained from the ice, so that the outwashes lie on the eastern side of the terminal moraines.

Either because of more rapid melting or of a greater concentration of waters flowing over the surface of the ice, the narrow terminal moraines in the eastern side of the county are flanked by the largest outwash deposits. Sand and gravel outwashes border the Waubay Moraine on the eastern side for all but three miles of the entire length. The second outwash lies between the Waubay and the Pickerel Moraines, being formed when the ice stood at the latter position. The third outwash was formed in front of a portion of the Webster Moraine and can be traced from the Waubay Lakes through Rush Lake into Blue Dog Lake. Two other large outwashes occur about the northern end of Pickerel Lake. One lies in front of the small moraine which runs northward from the northern end of the lake, and the other one lies between the small terminal and the Webster Moraine to the west.

Few outwashes were formed along the front of the Bristol Moraine, though it is the largest terminal moraine in the county. Apparently the ice melted more slowly when its stand occurred at this place than it did at the stands in the eastern portion of the county, and the waters were taken up by seepage into the underlying drifts or by evaporation. Though there are very many gravel pockets and knobs in the moraine, there are only two areas of outwash of any consequence, and they lie in Oak Gulch and Troy townships (T. 120 N, R. 58-59 W.). Each of these occupies a surface area of about four square miles.

## Kame and Esker Fields

Knobs and ridges of gravel and sand which are formed by deposition of this material in cracks or holes in the ice occur in considerable abundance in all the terminal moraines. Most of them are small and scattered, as will be noted from an examination of the accompanying map. One large field, however, lies at the southern end of the Webster Terminal Moraine in Wheatland and

Eggland townships (T. 120 N., R. 54-55 W.). In this field there are eight or nine ridges, some of them one to two miles in length and all trending toward the southeast. Between the ridges and in the same vicinity are a multitude of round, knobby hills (kames) of sand and gravel. These ridges and knobs vary in height from a few feet to forty or fifty feet and form striking features of the topography.

## Lakes

Lakes and swamps abound on the Coteau. The hollows between the hills in the terminal moraines all form basins in which water collects whenever there is a surplus. The swells and swales of the ground moraine also form depressions which result in swamps and shallow lakes during wet seasons.

Only a relatively few of these depressions, however, are large enough and properly situated to make permanent or semi-permanent lakes. Two regions stand out as particularly suitable to lake formation, one a north-south belt through the middle of the county, and the second occupying the eastern third of the area.

The first of the two is a depression on the Coteau which carries a multitude of steep walled basins that in normal times hold water. Boulder lines, caused by ice, appear in many of these high up on the sides of the basins. The vegetation, even after the periods of dry years which had preceded the summer of 1934, indicated more moisture in these basins than in the surrounding country. The northern end of this chain of lakes lies four miles west of Roslyn and contains lake basins and depressions for a width of five miles. The belt can be followed southward past Holmquist, Butler, and Lily. The northern end lies in the Bristol Terminal Moraine, the middle in the ground moraine between the Bristol and Webster Terminals, and the southern end in the Webster Moraine.

The depression in which these lakes lies is a large valley made previous to the coming of the Wisconsin Ice sheet. The southern end appears to connect with the depression in Codington County in which Swan Lake lies and which can be followed southeastward into the Big Sioux Valley. Most of the basins in this belt are merely swamps, but eight of them hold water enough of the time so that they are rated as lakes on maps of the county. All lakes of this belt were dry the summer of 1934.

The second lake region is in the eastern side of the county and includes the large and permanent lakes. Pickerel, Enemy Swim, Blue Dog, Rush, and Bitter Lakes and the large Waubay chain are among them. These lakes lie in the depressions between the terminal moraines and in the outwashes of sand and gravel in front of the moraine.

Pickerel Lake, the deepest of the group, has never gone dry. Its southern half lies in a hollow formed in the back of the Pickerel Moraine. Its northern half, however, lies in outwash as though a huge block of ice had been separated from the main ice sheet, covered with debris, largely sand and gravel, and finally melted, leaving a great hole which subsequently filled with water, forming Pickerel Lake. The gravels to the east of the lake may have furnished much of the water, as the outlet is to the west. In rainy seasons the overflow finds its way into the Waubay Lakes through a channel leaving the lake at about the middle of its western side.

Enemy Swim, Blue Dog, and Bitter Lakes are in depressions in a gravel outwash, apparently formed in much the same manner as Pickerel Lake when the ice front stood at the location of the Pickerel Moraine. A gravel channel connects all three of these lakes, through which the waters discharging from the melting glacier apparently found their way around the northern end of the Waubay Moraine and into the Big Sioux Valley. They are, therefore, spring fed and spring drained.

The Waubay Lakes and Spring Lake lie in depressions between the Waubay and Pickerel Terminal Moraines. The Waubay lakes are surrounded by clay hills of the Waubay Moraine, but Spring Lake, Minnewasta, and Rush Lake lie in a gravel outwash which spilled through the channel occupied by these lakes and joined the channel in which Blue Dog and Enemy Swim lie at Waubay. Its water then proceeded around the northern end of the Waubay Moraine into the Big Sioux Valley.

Most of the lake basins are shallow, though the deepest, Pickerel, is reported to have sixty feet of water in places. Enemy Swim contained 25 to 30 feet of water in the deep channels during the summer of 1934.

## ECONOMIC GEOLOGY

The mineral products of Day County include water, sand and gravel, and clay. Though these are not as spectacular as metallic products or fuels, they are much more important, since they furnish the basis for much of the comfort and prosperity of an agricultural region. Water is of prime importance wherever human beings have to live, and structural materials for making of houses and barns, roads, public buildings, etc., are resources of vital importance in the development of any country.

## WATER SUPPLIES

Three sources of water supply are available: (1) Surface water; (2) Glacial-water-sand; (3) Artesian water.

### Surface Water

There are no large streams in Day County, and surface water is confined largely to that which stands in lakes and ponds and flows intermittently through the stream channels of the western side of the county. These streams are too small to be important as sources of water supply, though they do furnish temporary watering places for stock. One valley south of Pierpont has been dammed, and its stream supplies a fairly large artificial lake.

A large spring issues from the Coteau Escarpment at Crandall in the southeast corner of the county and has been used satisfactorily for irrigation. Its waters were flowing with little or no diminution during the very dry summer of 1934. It should be classed as a permanent spring. Other springs occur along the base of the Coteau Escarpment but have not been put to use. Most of them do not have a large flow of water.

The largest amounts of surface water lie in the lakes and sloughs. That in the sloughs is not readily available for direct human use, but that in the lakes can be made an important source of water for communities like Webster and Waubay for watering stock and for recreation. This last use is now the most important and probably will be for a long time in the future, as these lakes can serve as recreation places for a large community.

The lakes are spring fed and with the exception of Bitter Lake all have outlets either over the surface or underground through gravel channels. Their waters are thus kept fresh by a slow but constant change.

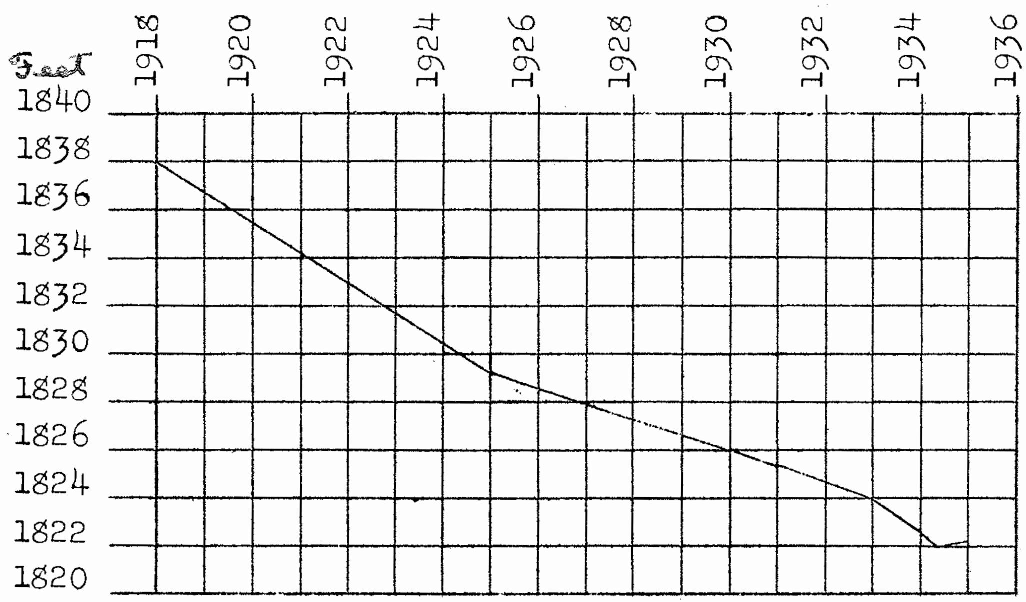
#### Pickerel Lake

Pickerel Lake, lying deeply imbedded in its surrounding morainic hills, is fed by runoff from a very small drainage area immediately surrounding it. In dry weather it has to depend on seepage through the clay, and water furnished by some large springs on the eastern side of the lake. So far as could be ascertained it has no outlet except an overflow channel on the eastern side which operates only when the lake level is high. Apparently this is sufficient to keep the water fresh, and the great depth of the depression in which the lake lies, together with its relatively small surface area and its protection from the wind, reduces evaporation and thus has kept water in it during the most

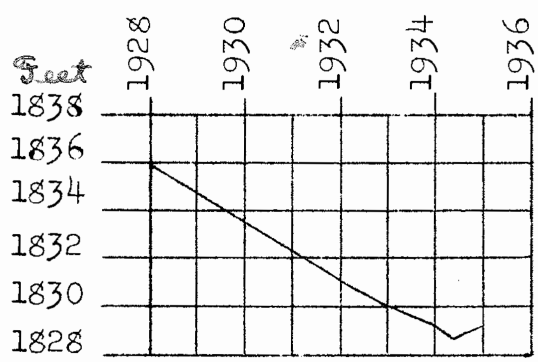
Fall of Water Surface

of

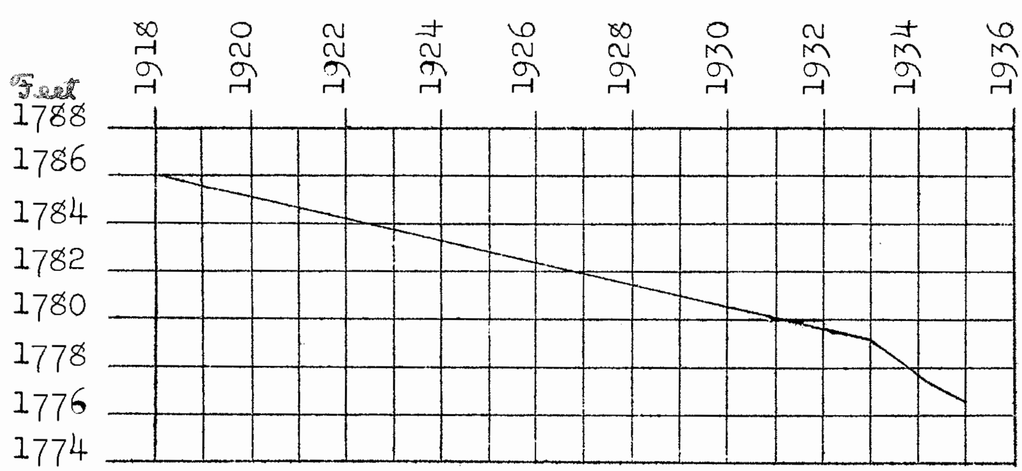
Day County Lakes




Enemy Swim Lake




Pickerel Lake




Minnewasta Lake

severe drouths on record. Through the courtesy of Mr. Ury Dahling, the Deputy State Game Warden located at Pickerel Lake, it was possible to locate the beaches formed by various levels at which the lake has stood during the past seven years. Measurements on these beaches show that the level of the water surface has not lowered as rapidly in Pickerel Lake as in those shallow lakes that cover large areas. The following table gives approximate sea level elevations of the lake's surface for years in which it could be determined.

| Year | Approx. Sea Level |
|---|---|
| 1928 | 1836.3 |
| 1932 | 1831.5 |
| 1933 | 1830 |
| June, 1934 | 1829.3 |
| Aug. 10, 1934 | 1828.6 |
| May 31, 1935 | 1829.2 |

This table shows a steady lowering of the lake level averaging about one foot a year during the dry seasons to the end of 1934. It is also interesting to note that the abundant rains during the spring of 1935, amounting to more than seven inches at Webster, were not sufficient to raise the level of the lake.

## Enemy Swim Lake

Enemy Swim is the second lake which did not go dry during the severe drouths of 1890-93. During this drouth its surface area was reduced to less than two thirds of its normal size, however, and the arms, or bays, were entirely dry. It was dry for so long that a cottonwood grove grew across the south bay.

This lake lies in a gravel channel between two ranges of morainic hills. The Waubay Moraine reaches its southeastern corner and forms the east bluffs of Campbell's Slough, which is in reality a southern arm of the lake. The northern and western sides of the lake lie against the Pickerel Moraine, which forms a long horseshoe around its northern end. The south and east sides are flanked with the gravel hills of the outwash in front of the Pickerel Moraine. The drainage area is very small considering the surface area of the lake, being confined to the slopes of the hills immediately surrounding the lake. The permanency of the water level, therefore, has to depend largely on water fed into the basin from the surrounding gravels. In order to maintain a constant water level in a lake of this area, 835,000,000 gallons of water per annum must be supplied, mostly by springs, to counteract the loss by evaporation alone. That is at an average rate of 2,290,000 gallons per day. During normal times the ground water level will rise in the gravels, raising the level of the lake with it. During dry times, however, this ground water level falls and fails to supply the losses, thus lowering the lake level.

Outlet is through evaporation and seepage toward the south. An outlet channel from Campbell's Slough allows water to escape over the surface in times of very high water by way of the slough into Blue Dog Lake. As has been stated, Enemy Swim Lake is also connected to Blue Dog Lake by a gravel channel which allows water loss by seepage or underflow which eventually reaches Blue Dog Lake. It is impossible to estimate this loss from the data available but it will be far below that caused by evaporation. It is the most important of the two losses, however, for it keeps the lake fresh by removing the salts with the water which would otherwise accumulate, causing the lake to become bitter or "salty". So long as the lake has this outlet and is replenished by fresh water from springs and rain, its waters will remain fresh, but if the outlet should be cut off entirely and all water loss be caused by evaporation, its waters would in time become salty through the accumulation of undesirable salts brought into it by ground water.

Through the courtesy of Mr. Jack Rummel, Prof. S. R. Lipscomb of the Northern State Teachers' College Biological Station, and others familiar with the lake, it was possible to identify several of the older lake beaches and obtain the following figures on the fall of the water level during the recent drouth:

| Year | Sea Level Elevation (Approximate) |
|---|---|
| 1918 | 1838 (highest beach on lake) |
| 1925 | 1829.2 |
| 1931 | 1825.6 |
| 1933 (August) | 1823.9 |
| 1934 (July 12) | 1822.6 |
| 1934 (Aug. 10) | 1822 |
| 1934 (Aug. 30) | 1821.9 |
| 1935 (May 31) | 1822.3 |

According to reports, the lowest level of the lake occurred in the middle of the winter, during December and January, but the elevation was not recorded.

It is of interest to note that though the lake had dropped over fifteen feet during the severe drouth preceding 1935, it did not fall as low as in the drouth which occurred during the early 1890's. No records were kept of the lakes at that time, but reports from the memories of many old timers agree that water levels were considerably lower at that time than during the recent drouth. During that drouth the southern arm of Enemy Swim was a poplar grove, where during the summer of 1934, eight to ten feet of water lay. The stumps of poplars five to ten years old were noted under four and five feet of water in the summer of 1934. Some reports state that the lake was separated into two small lakes by a large bar which lay north and south across the middle of the present lake.

## Blue Dog Lake

Blue Dog Lake lies at the northern edge of the city of Waubay and at the southern end of the gravel channel between the Pickerel and Waubay Moraines. It also is largely spring fed, since its drainage is confined to the immediately surrounding hills. Its inlet, therefore, is largely seepage from the gravels to the north of it. As has been pointed out, Enemy Swim and Blue Dog Lakes are in the same gravel channel. Blue Dog Lake, however, lies about forty feet lower than Enemy Swim, making a gradient of eight to nine feet per mile between the two. Any water, therefore, which enters the gravel channel will move toward Blue Dog Lake. This seepage has been sufficient to keep water in the lake during the recent drouth, though the evaporation loss would approximate 500,000,000 gallons per year (1,3000,000 per day).

Blue Dog Lake has an area of about two square miles and is much more shallow than the two lakes which have been described. The highest beach is but ten feet above the water level of August, 1934. With this shallow basin and proportionately large surface it is rather unusual that the lake should be as permanent as it is.

Its outlet is largely seepage, as there are no streams discharging from it. An indefinite channel connects it with Bitter Lake but carries a stream only in times of high water. The surface of Bitter Lake lies about twenty-five feet below that of Blue Dog, allowing a water gradient of eight or ten feet to the mile to be formed in the gravels which connect the two. This outlet has served the purpose of keeping the lake water fresh. Though the seepage is far less than evaporation loss, it is sufficient to carry off the excess salts which would otherwise accumulate and make the water undesirable for ordinary purposes.

Measurements on the fall of the water level in Blue Dog Lake during the recent drouth were not made because it was impossible to locate beaches accurately. Measurements made on August 20, 1934, however, showed the water level at 1782.7, while the highest beach lay at an elevation of 1792.8.

## Bitter Lake

Bitter Lake is perhaps the most interesting of the Day County lakes from a geological standpoint. This lake lies at the southern end of the gravel channel containing Enemy Swim and Blue Dog Lakes and is also connected to Rush Lake and the Waubay Lakes through a gravel channel. It is surrounded by clay hills on all but the north side, where the gravel channels form an inlet whence nearly all its water is received. Since its bottom and sides are relatively impervious clay and there is no overflow channel, water escapes from this lake by evaporation only. The lake is shallow but has an area of approximately four square miles. Thus it forms a great evaporating pan for water seeping from all the lakes to the north of it. Using a conservative figure, this lake will evaporate 1,115,135,000 gallons of water a year, or more than 3,000,000 gallons a day. This large evaporation has caused a concentration of salts sufficient to give the water the taste from which the lake derived its name. During the summer of 1934 Bitter Lake was dry, but it had water in it before the spring of 1935.

## The Waubay Lakes

The Waubay Lakes lie on the front of the Webster Moraine and in surface area are the largest bodies of water in the county. They are mapped as five separate lakes, though in reality they all lie in one great depression reaching from a point a mile northeast of Webster to the city of Grenville, a total length of nearly ten miles. Their total area covers about fourteen square miles. The northernmost lie in the depression between the Webster and Pickerel Moraines, but the largest of the lakes lies deeply embedded in the Webster Moraine, forming a great bay or reentrant in its front.

These lakes are shallow, and have a comparatively large surface area. For this reason they have suffered more in times of drouth than the smaller lakes. They did not become entirely dry during the recent drouth, though the water level was far below normal. The sea level elevation of the water surface was approximately 1753 feet in August, 1934. Boulder beaches on the easternmost Waubay Lake indicated that at some time the water level had reached an elevation of approximately 1785, about thirty feet above the present level.

These lakes have no large feeding area, their drainage area being confined to hills less than a mile from the lake border. As the surrounding rocks are all glacial clays, there can be no such collecting area as is to be had by those lakes which are fed by gravel channels. The source of water, therefore, is confined to the immediate run-off and that which can seep through from the clays which make its basin. Such seepage is always slow, and the lake level, therefore, can be lowered more rapidly in times of excessive evaporation than in those lakes in which inflow is more rapid. This slow seepage, however, tends to reduce the speed with which the evaporation from the lake can lower the water table in the surrounding area and tends to make for a more rapid comeback in the normal years following a drouth.

The outlet for the Waubay Lakes is a gravel channel which leaves the lake depression at about the middle of the big central lake and passes thence through Minnewasta and Rush Lakes, where it joins the channel containing Enemy Swim and Blue Dog Lakes and thus ends at Bitter Lake. In times of high water it overflows into Rush Lake, but there is also an underflow through the gravel channel connecting Waubay Lake with Bitter Lake. This is not as active a drainage as that of the lakes in the eastern channel since the elevation of the Waubay Lakes is much nearer that of Bitter Lake than are the elevations of the lakes in the eastern channel. In August, 1934, the difference in water level between Waubay Lake and Bitter Lake was but seven feet. The evidence of the highest beaches on both lakes does not increase the slope greatly.

The fact that the water level in Minnewasta Lake was twelve feet higher than that in Lake Waubay in August, 1934, when both were at a very low level, indicates that the gravel channel does not extend to the level of the bottom of Lake Waubay. There is evidently a ridge of clay lying beneath the gravels between Waubay Lake and Minnewasta Lake, since Spring Lake, East Waubay, and Waubay, which are separated by gravel divides only, have elevations which differ by only a few feet.

Upon dessication, these lakes show considerable alkali, and it is probable that their poorer drainage will make the concentration of salts higher than in the lakes of the eastern channel.

<u>Spring Lake</u>

Spring Lake is in reality part of the Waubay chain, as it lies in the same basin and is separated from East Waubay Lake by only a few hundred feet of gravel. It differs from the other lakes of the chain in being fed by some large springs which debouch from the hills at the northeastern end of the lake. These large springs pour sufficient water into the lake to maintain it during the dryest seasons. It is reported that it has never gone dry.

The springs have flowed with undiminished volume during both wet and dry seasons according to report. There has been a suggestion that the springs were draining Enemy Swim Lake which lies less than a mile to the east and is considerably higher. There are no surface indications of such a connection, the hills making the divide being glacial clays like the rest of the Pickerel Moraine of which they are a part. An electrical sounding was made in the hope of discovering a buried gravel channel under the divide, but the results were negative.

That the water comes from Enemy Swim is evident from the fact that the two lakes are so near together and lie at such different levels. The drop from the lake level of Enemy Swim to Spring Lake in August, 1934, was fifty-four feet in a distance of about half a mile. The highest of the big springs breaks out at an elevation of 1798, twenty four feet below the level of Lake Enemy Swim and thirty feet above the level of Spring Lake. The springs lie in a small valley that heads directly toward the southwestern tip of Enemy Swim Lake, and the owner of the property reports that in normal times the bottom of the valley is too wet for haying twenty feet or more above the spring.

It appears, therefore, that the springs are formed by the natural seepage of water through glacial clays increased somewhat by the pressure generated by the sharp drop between Enemy Swim and the springs and localized by the sharp valley in which the springs break out. It is probable that local gravel pockets aid in increasing the flow. It is certain that these springs do not have a vital effect on the water level in Enemy Swim Lake.

Little information was obtainable on the fluctuation of the levels of Spring Lake. The following shows that there has been considerable fluctuation, however, and that the water level has been nearly thirty feet higher than it was in 1934.

| Year | Approx. Sea Level |
|---|---|
| Highest boulder beach, date unknown | 1797 |
| Sand beach, date unknown | 1786 |
| 1933 beach | 1771 |
| August 1934 beach | 1768 |

Minnewasta Lake

Lake Minnewasta lies directly across the gravel channel between Waubay and Bitter Lakes. It is a small lake with an area not exceeding a square mile, which is divided into two by a gravel bar in low water. It is chiefly of interest in showing that the clay bottom of the gravel channel prevents the best drainage of the Waubay Lakes. Whether the Indian name of "Minnewasta" (good water) has any significance is a question, but it showed little alkali during the dry summer of 1934, and the water was usable for stock. This lake showed rather pronounced beaches, and it was possible to get some information on the rate of decline of the water level.

Water Levels on Lake Minnewasta

| Year | Approx. Sea Level |
|---|---|
| Highest beach, date unknown | 1790.8 |
| 1917-1919 beach, exact date not known | 1786.6 |
| Spring 1933 beach | 1779.3 |
| Spring 1934 beach | 1777.8 |
| August 1934 water level | 1776.6 |
| May 30, 1935 water level | 1776.3 |

In ordinary times this lake drains into Rush Lake, but its elevation is so near that of Rush Lake that with an overflow of that lake water backs into Minnewasta. It is reported that during a time of high water some years ago fish from Blue Dog Lake were caught in abundance in the outlet channel near Minnewasta. The fact that at low water Blue Dog Lake has an elevation of approximately 1783, while the bottom of Rush Lake is 1773 and the low water level of Minnewasta is 1776 shows how such a reversion of normal drainage could take place.

## Rush Lake

Rush Lake lies in the gravel channel between Waubay and Bitter Lakes. Its basin is broad and shallow and was drained some years ago to get rid of the marsh land which it created. Its bottom lies at an approximate elevation of 1773 feet. It was at one time an important lake for duck hunting and certain kinds of fish and could be made so again if occasion demanded. This lake would have to be entirely spring fed, deriving its waters from the gravel channel in which it lies. Its elevation, however, would permit of its sharing water with Blue Dog Lake. The stoppage of surface drainage would allow water to again fill the lake, and if the underflow through the gravels into Bitter Lake were not hindered, the water would remain fresh.

## Summary of Lakes

From the foregoing it is evident that the lakes of eastern Day County divide themselves into two systems according to drainage. The group belonging to the eastern drainage channel should include Enemy Swim, Blue Dog, and Bitter Lakes. These have suffered least from the drouth of any of the lakes except Pickerel. Their waters are kept fresh by a relatively rapid change due to the differences in their elevations. The low water elevations of this chain in 1934 were:

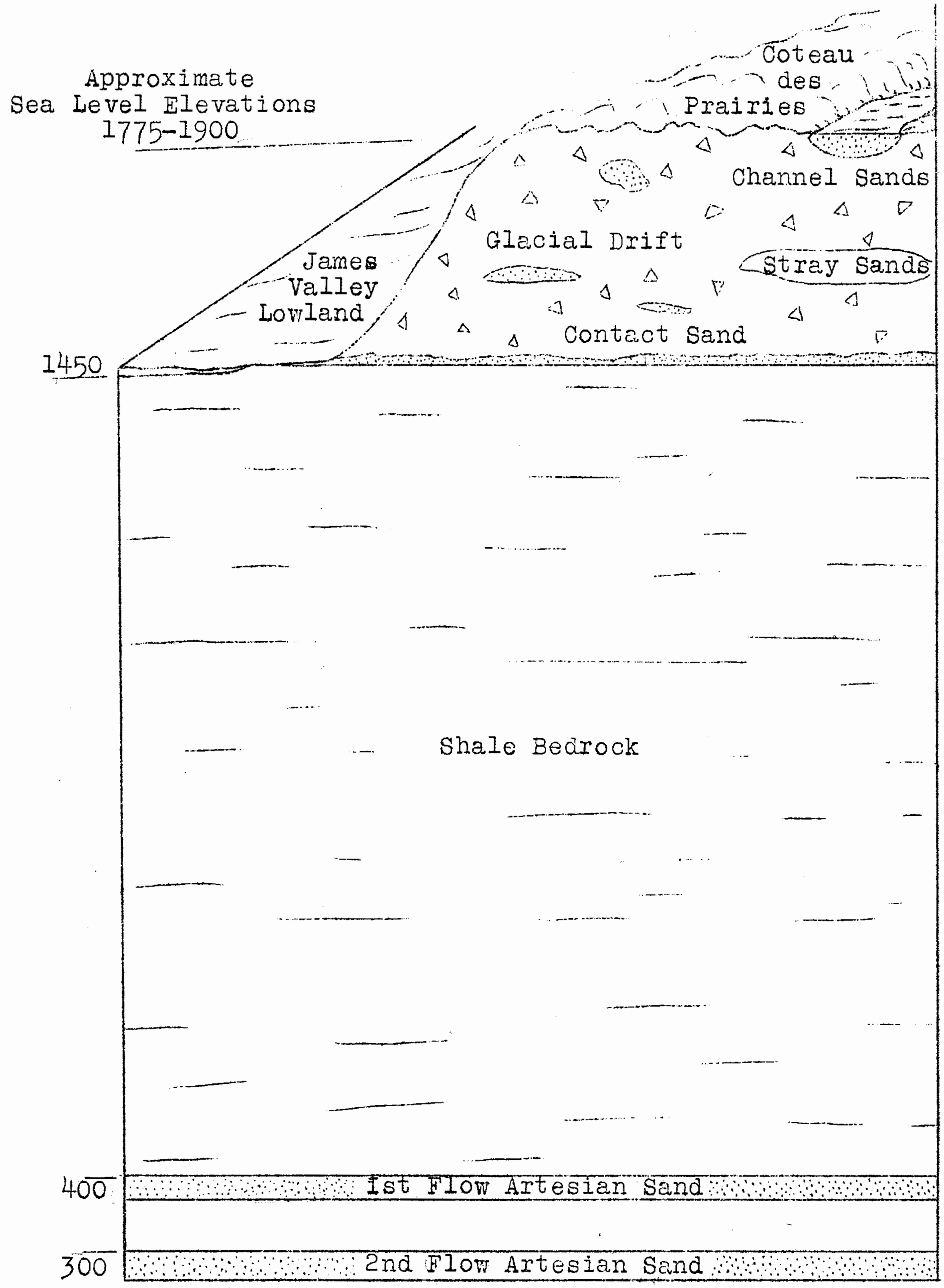
| | |
|---|---|
| Enemy Swim Lake | 1822 |
| Blue Dog Lake | 1783 |
| Bitter Lake | 1757 |

This is a total drop of sixty-five feet at an average rate of about eight feet per mile.

The second chain of lakes will include the Waubay Lakes, Spring Lake, Minnewasta Lake, and Rush Lake, which are all controlled by the western gravel channel. Pickerel Lake might be added to this chain, since it overflows into it. Low water elevations in 1934 were as follows:

| | |
|---|---|
| Pickerel Lake | 1828 |
| Spring Lake | 1768 |
| East Waubay Lake | 1765 |
| Waubay Lake | 1764 |
| Minnewasta Lake | 1776 |
| Rush Lake | 1773 |
| Bitter Lake | 1757 |

The total drop of this chain, exclusive of Pickerel Lake, is only eleven feet or but little more than one foot per mile.




GEOLOGIC COLUMN SHOWING

POSITION OF WATER SANDS IN DAY COUNTY

## Shallow Ground Water Supplies

A number of water filled gravel channels, innumerable stray sand pockets, and three extensive beds of water sand offer the county an abundant supply of easily obtainable ground water of excellent quality. The first two sources and one of the extensive water sands are of glacial origin and lie nearest the surface, while the two remaining water sands are in the underlying bedrock and can be reached by deep wells only. The glacial sources must all be pumped, but the bedrock sands yield water under artesian pressure which will flow in the western part of the county. These sources are ample to supply the well water needs of the county under almost any future condition that may be predicted. To insure the fullest use to the best advantage, however, certain suggestions will be incorporated in the following descriptions of these sources.

### Shallow Wells

During times of normal or more than average rainfall, water can be found in dug wells, sand point wells, and similar wells in most of the low places in the county. Such supplies are liable to fluctuate considerably, however, and are especially unreliable in times of drouth. In general, the lower the well and the steeper the hills about the depression in which it is dug, the better chance it has of furnishing a permanent water supply. Thus some wells in and near the bottoms of sloughs were furnishing water during the dryest part of 1934.

The volume supplied by such wells is usually small, since most of them are dug in glacial clay which unless very sandy, allows only a slow seepage into the well. They are adequate for farm supplies where the number of head of stock is not large, but can not be depended upon for quantities necessary to supply a town or a large stock farm.

Considerable volumes of water and fairly permanent supplies can be obtained from sand point wells drilled into the gravel channels indicated on the geologic map. The outwashes about Pickerel Lake and the two channels in which the eastern lakes lie lend themselves especially well to such development. Water from such wells can be developed in sufficient volumes for all ordinary ranch or city purposes. Similar developments, though on a less extensive scale, can be made from the sands and gravels which surround the intermittent lakes and sloughs east of Lily and Butler and north of Holmquist and Bristol. These could be developed into excellent farm supplies but are not sufficiently extensive for city supplies. Similar surface sand deposits are to be found along some of the streams at the base of the Coteau Escarpment east and south of Andover and should be capable of similar development.

Stray Glacial Sands

As has been pointed out in the description of the geology of the county, the bedrock is covered with glacial drift over the entire county. In the James Valley Lowlands it averages only about fifty feet thick, but under the rest of the county (the Coteaus), four hundred to five hundred feet thick. In the deposition of this material pockets of sand and gravel of various sizes form at unpredictable places. Wherever a current of water from the melting ice has sufficient velocity to wash the clay out of the debris it is carrying, a gravel deposit is formed. The gravel deposit is then buried in glacial clays. Almost any sizable road cut will disclose one or more small pockets of this kind.

If the pocket of gravel lies under the water table, it makes an excellent source of water, for it contains much more wall space from which water can seep than could be obtained by any of the ordinary methods of well making. Such sand pockets may be of any size, from that of a bushel basket to those whose areas are figured in square miles, and may be found at any depth, from fifty feet in the James Valley Lowlands to five hundred feet on the Coteaus. Because of their mode of origin, it is impossible to predict their location, depth below the surface, or the volume of water they could supply from the information at hand. Wells drilled near others producing from such a sand have a fair chance of hitting the same sand, but the proximity of such a well holds no guarantee that a new well will produce from the samd pocket. The only method that can be pursued in developing these pocket sands is that of drilling until a pocket is encountered which will give the required flow of water.

The city of Webster is being supplied from such a pocket which is about twenty-eight feet in thickness and which was struck at a depth of 210 feet. This sand furnishes an average of 80,000 gallons of excellent water per day. It is under an artesian head which raises it about one hundred feet above the sand.

The Contact Sand

This sand lies at the base of the glacial drift and the underlying shale bedrock. It is a persistent zone of sand and gravel which can be seen at some of the bedrock outcrops in the vicinity of Andover and Pierpont and has been struck in wells as far east as Roslyn and Webster. No wells have been drilled deep enough to strike it east of the two just mentioned, but its continuity beneath the rest of the county indicates that it should be found considerably east of the known locations and probably underlying the entire county.

As is the case with most glacial sands, this one appears to be quite variable in thickness and composition. On the outcrops south of Andover only two feet of gravel occurred under fifteen feet of till. Between Andover and Pierpont, however, ten feet was exposed at one outcrop and twelve feet of sand and gravels and water laid silts at another. North of Pierpont seven feet were noted in one outcrop, while more than five were exposed in another. At Langford, on the county line six miles north of Pierpont, sixteen to twenty feet appear in wells and pits drilled in the city. Drillers report penetrating the sand for twenty feet in wells drilled on the Coteau before striking bedrock. The persistence of the sand is rather remarkable in view of the great variation in its thickness.

The character of the sand is equally variable, though it contains sufficiently coarse material at some levels to furnish abundant water. The drillers describe it as an alternation of shale and sand, and the outcrops bear out the description. Shale flakes occur in beds or clay zones which act as partings separating the various layers of sand and gravel. At Langford these shale flakes occur nearly twenty feet above the solid shale bedrock.

The following descriptions were made of the sand at the outcrops and will serve to illustrate its variability:

Gravel Section

2 miles east and 4.7 miles north of Pierpont
0.3 miles south of the NE. Cor. Sec. 6, T. 124 N., R. 58 W.

| | |
|---|---|
| 5 feet | Gravel; poorly sorted; not well exposed. |
| 26 feet | Shale Bedrock. |

Gravel Section

1¼ miles north of Pierpont
SW¼ Sec. 29, T. 124 N., R. 58 W.

| | |
|---|---|
| 10 feet | Buff glacial till. |
| 7 " | Sand and gravel in 6 to 12 inch beds which are quite distinct and fairly well sorted. The sands are medium grained and clean, but the gravels contain considerable clay and shale. Some beds are made of shale pieces more or less mixed with pebbles and partly cemented with iron. There are three or four such zones 1/2 to 2 in. thick in this section. |
| 35 feet | Shale bedrock. |

Gravel Section

One mile east and three miles north of Andover
SW¼ Sec. 13, T. 123 N., R. 59 W.

| | |
|---|---|
| 13 1/2 ft. | Buff glacial clays with 1 1/2 ft. soil on top. |
| 8 ft. | Sand, medium to fine grained. |
| 2 ft. | Gravel. |
| 21 ft. | Shale bedrock. |

Gravel Section

1.9 miles north of Andover
NW¼ Sec. 26, T. 123 N., R. 59 W.

| | |
|---|---|
| 15 ft. | Glacial clays (till). |
| 3 ft. | Gravel; medium to coarse; well sorted. |
| 7 ft. | Water laid silts. |
| 10 ft. | Gravel; medium to coarse; fairly well sorted. |
| — | Shale bedrock. |

Gravel Section

Four miles south and three miles west of Andover
SW. Cor. Sec. 20, T. 122 N., R. 59 W.

| | |
|---|---|
| 15 ft. | Glacial drift; coarse gravel at the base not well exposed but not more than a foot or two thick; pebbles up to one inch in diameter. |
| 30 ft. | Shale bedrock. |

The water is frequently under pressure which raises it above the top of the sand. Several 150 to 200 foot wells at the base of the Coteau Escarpment have given artesian flows from this sand.

The depth necessary to reach this sand will vary with the location. In the James Valley Lowlands the contact varies from twenty-five to fifty feet. On the Coteau it varies from four hundred to five hundred. In general the depths of the wells using this sand in the vicinity of Roslyn is approximately four hundred feet, while those near Webster are nearer five hundred feet. Two and one half miles south of Roslyn a well was drilled to the shale bedrock, which it reached at 410 feet. A well on the George Brady farm five miles south and one and one half miles east of Webster was stopped in "slate and sand" at a depth of 502 feet. The city well at Butler, which appears to draw water from this sand is 337 feet deep.

The city of Webster drilled a well into the contact sand to a depth of approximately five hundred feet. It is reported that it furnished an abundance of soft water but contained so much "soda" that the city abandoned it for the hard water from the shallower sand.

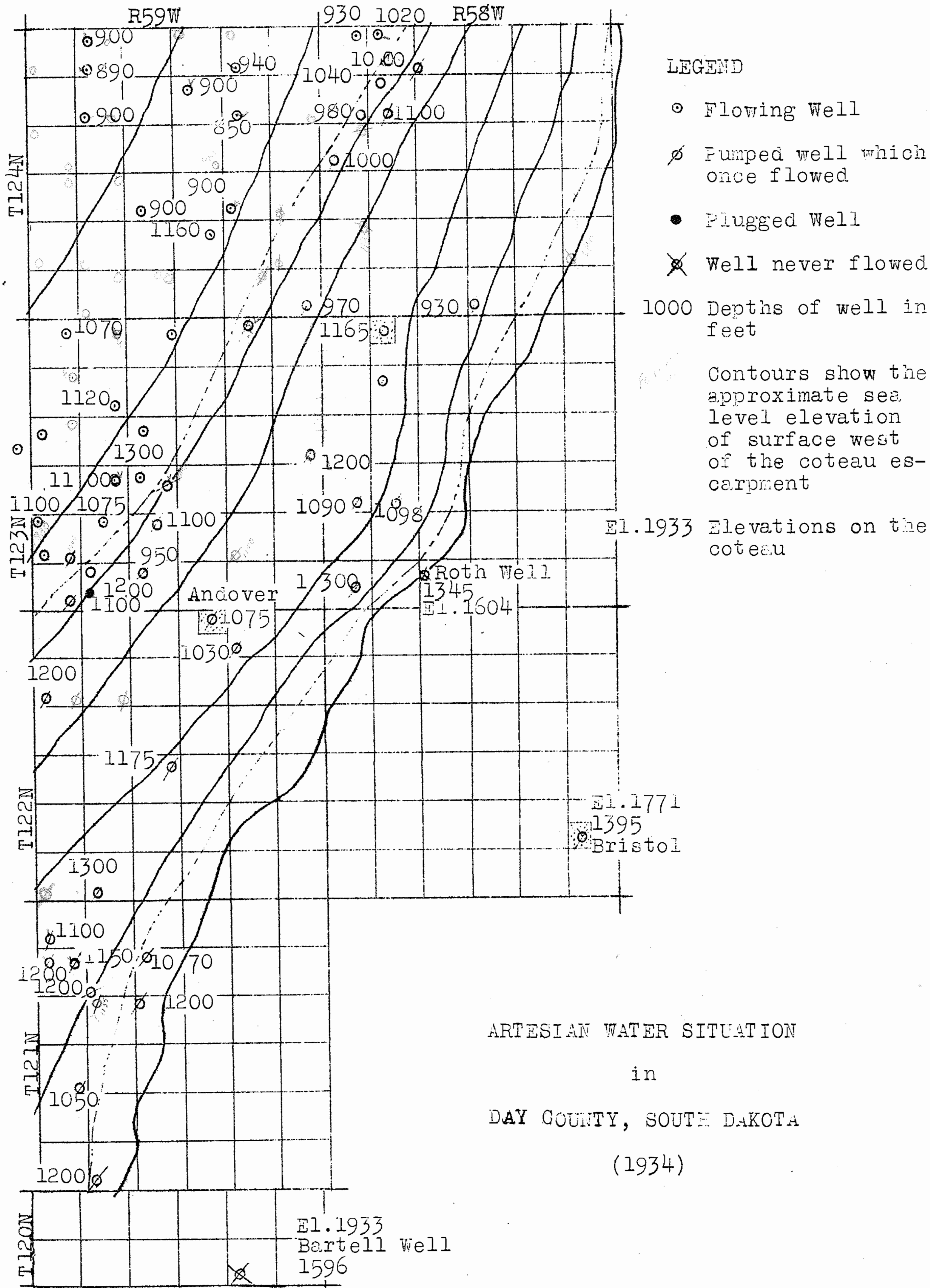
The well at Butler, however, produces hard water. At Langford also the contact sand is reported to furnish an abundance of hard water. It is not known what causes this difference in the character of the water, but it is important to note that the zone does not give the same quality of water in all localities. The lenticular character of glacial sands and lack of rapid circulation could account for the difference.

## Artesian Supplies

The use of artesian water has been confined to the James Valley Lowlands, though artesian sands underlie the entire county. During the early days of artesian well drilling, shortly after the beginning of the present century, many wells were drilled in the James Valley and furnished large supplies of water under heavy pressures. Test wells were tried on the Coteaus by the city of Webster, by the Milwaukee Railroad at Bristol, and on the Bartell Ranch near the edge of the Coteau. None of these flowed, however, because the surface elevation was above the level to which the pressure could raise the water. Flowing wells from the artesian sands that have been tapped, therefore, have always been confined to the lowlands, but this supply can be used on any part of the Coteau by pumping if there should be a demand for it. Whether untapped artesian sands will have sufficient pressure to make flowing wells in these highlands remains to be seen.

Since the opening of these wells there has been a steady decline in head which has caused many of them to cease flowing and threatens to make flowing wells an impossibility in Day County. The preservation of this head is a large and important problem and will be further discussed with the consideration of the separate artesian sands.

Two artesian sands are known to exist in Day County lying at the bottom of a thick section of black shale and separated by about one hundred feet. They can be distinguished also by the character of the water each produces. The upper sand furnishes a soft water and has been used almost exclusively in spite of the fact that it carries such a high percentage of alkalies that it is impossible




ARTESIAN WATER SITUATION

in

DAY COUNTY, SOUTH DAKOTA

(1934)

to use it for irrigation. According to the testimony of those who have tried it, one season's use of the water will ruin the soil in a garden and cause hard pans to form. The lower sand furnishes a water that can be used for irrigation indefinitely but is not popular because of its hardness.

## The First Flow

The first flow is tapped at depths of 1000 to 1100 feet in the James Valley Lowlands and 1300 to 1500 feet on the Coteaus, depending on the topographic location of the well. It lies at an elevation of 250 to 350 feet above sea level. From the available data there seems to be a slight dip toward the west. The following figures are instructive, though they must be used with some caution, since well records from which they were taken were not kept in as much detail as is desirable for accurate geologic information. At Webster the first flow sand was entered at a sea level elevation of 356 feet, at Bristol at 376 feet, on the Bartel Ranch (about ten miles southwest of Bristol, Sec. 11, T. 120 N, R. 59 W.) at 337 feet, Andover at 400 feet, Pierpont and Langford at 265, seven miles west of Pierpont on county line at 246. Considering the distances between these points, the slight differences in elevation would flatten out till the sand would appear to be nearly horizontal.

## Decline in Artesian Head

As has been stated, the artesian head has been steadily declining in Day County. This decline is universal in the artesian area. Wells which have stopped flowing have been cleaned out and recased to no avail, and new wells come in at pressures corresponding to those in the old wells about them. The decline, therefore, is not due to lack of proper care of the wells but to a lessening of pressure of the water in the reservoir. Wells which once could throw a stream of water over a two story house now barely raise it into the basement of the same house. At Andover an artesian well was used as a source of power for the city, but it is now pumped. Some well owners are of the opinion that the rate has declined more rapidly in the last ten or fifteen years than previously, but no pressure records were kept to show it. Wells which once flowed now have to be pumped in a belt six miles wide, and so regular is the decline that it is possible to predict the rate at which this belt will widen.

It was not possible to make a systematic study of the decline during the course of this investigation, but information gathered in conversation with well owners and others on the heights of the water in their wells and measurements of flow in the wells about Andover and Pierpont, showed clearly the trend and will be instructive in considering the problem of conserving this flow of water.

The original head in this sand is fortunately available in those wells drilled to the artesian sand on the Coteaus during the early days of artesian drilling. These did not flow because of the elevation of the well curb. These wells, therefore, give the water column which the pressure could support in the days before extensive withdralals from the artesian basin here and in other parts of the state had lowered the pressure materially.

The easternmost well was drilled at the city of Webster, where the sand was struck at a depth of 1500 feet. This well did not flow, and no record was available showing the height of the water column. The elevation of the top of the well, 1856 feet, however, was too great to allow a flow.

A well drilled in 1904 on the Bartel Ranch in Sec. 11, T. 120 N, R. 59 W., struck the artesian flow at a depth of 1596 feet. Its elevation, 1933 feet, was too great to allow a flow, but the water rose to within 275 feet of the surface, giving a water column of 1321 feet. This figures a pressure of 575 pounds per square inch at the bottom of the well.

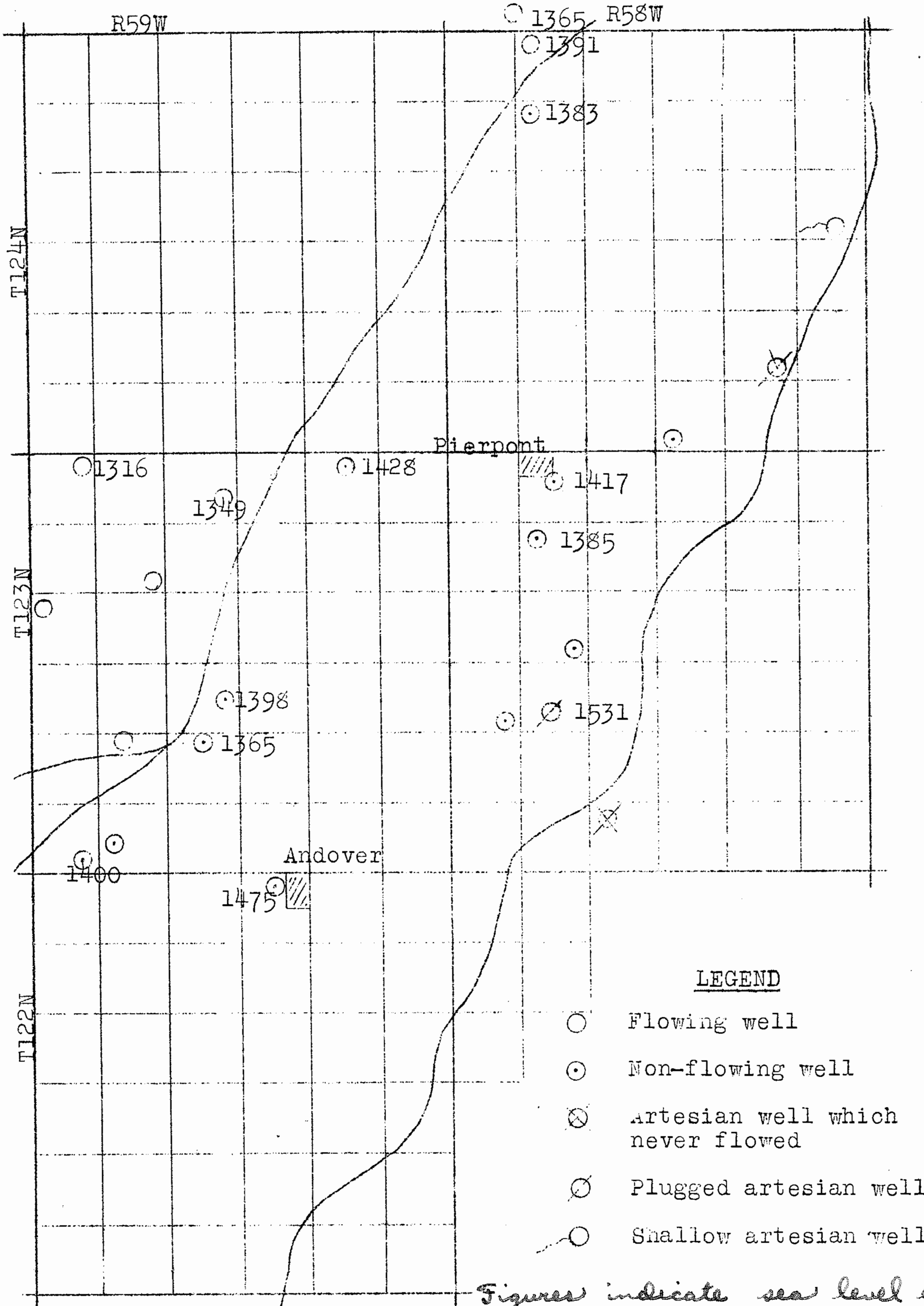
A well drilled about eight years later (1912-1913) on the Roth farm (Sec. 33, T. 123 N., R. 58 W.) did not flow. It entered the artesian sand at a depth of 1345 feet, and water rose to within twenty-seven feet of the surface, giving a water column of 1318 feet. This required a pressure at the bottom of the hole of 570 pounds. The curb elevation of this well was 1604 feet above sea level.

A well was also drilled by the Milwaukee Railroad at Bristol in 1911. Its curb elevation was 1771 feet, and the artesian sand was encountered at a depth of 1395 feet. The height of the water column was not available, but as this well did not flow it must have been close to the figure given for the other two wells, which would approximate the same pressure.

Though the data is rather meager, the evidence all points to a pressure of about 575 pounds as the artesian head in this county before extensive decline in the wells began.

The pressures in 1934 were indicated by data from three wells which had once flowed. The city wells at Pierpont, having a curb elevation of 1504 feet, reached the artesian sands at a depth of 1165 feet. In 1934 the top of the water column was eighty-seven feet below the surface. The column, therefore, was 1082 feet, which required a bottom pressure of 469 pounds per square inch. A second well one mile east and two and one half miles north of Andover with an elevation of 1404 feet had water standing six feet below the surface and a water column of about 990 feet, which figured a pressure of approximately 430 pounds per square inch. A well half a mile south of this last, however, (N¼ cor. Sec. 28, T. 123 N., R. 59 W.) had nearly the same elevation, 1400 feet, but

# ARTESIAN WATER HEAD IN DAY COUNTY SOUTH DAKOTA (1934)




Figures indicate sea level elevation at well curb.

the water level was reported as thirty-five feet below the surface. As this was pumped with a pitcher pump, the draw down due to water pumping could not have been great. The water column in this well was approximately 965 feet, requiring a bottom pressure of 417 pounds per square inch.

Though these figures vary somewhat, they bring out the fact that the head has dropped somewhere between 100 and 150 pounds since the artesian basin was first opened. Using the larger figure, it means that in the last twenty-five or thirty years the pressure in the artesian sand has dropped at a rate of about five or six pounds per year.

With more than half of the county's available artesian area without flowing wells, some figures on the probable lease of life that may be given the remaining flowing wells may be of interest. Records vary to such an extent, and there is such a lack of detail, that a single and absolute figure is impossible. By comparing the elevations and dates at which various wells ceased flowing, however, an approximation of the rate of decline can be obtained.

The height of the water column in the Bartel well is the best obtainable data for the early part of the century. In 1904 the top of this column stood at an approximate sea level elevation of 1658 feet. The Roth well came in in 1912 or 1913 with the top of the water column at 1577, but in 1911 the Pierpont wells at elevations of 1504 stopped flowing, and in 1910 a well a mile northwest of the Roth well stopped flowing at 1506 feet. From 1923 to 1928 four wells were reported as ceasing flow at elevations varying from 1391 to 1400. In 1931 a well at an elevation of 1390 feet stopped flowing, and in 1932 water failed to flow from one at an elevation of 1386 feet. The 1934 water level as reported varied from 1365 to 1417 feet.

From the above a great variety of figures may be obtained for the rates at which the head has fallen. Most of them, however, approximate six or seven feet per year. The curbs of the wells now flowing lie at elevations below 1380 feet. As the lowest part of the county, the northwestern corner, lies at an elevation of approximately 1280 feet, wells in this region should cease flowing in about fourteen or fifteen years if the present rate of decline is not stopped.

The preservation of artesian head has been discussed at length in so many places that it is unnecessary to go into details in this report. Suffice it to say that the lowering head is not due primarily to local waste. There are no large users of artesian water in the county, all the water that is used being consumed on farms, and these from small one and two inch wells. Discharges were measured at a number of wells in different parts of the artesian area, and none of them showed a production of more than two or three gallons per minute. The major cause lies in wastes and usage farther west where farm wells are very numerous and where cities have used and wasted enormous quantities from large wells, reducing the pressure in the entire James Valley section of the artesian basin. The remedy lies in better control of wells. The plugging of wild wells, recasing or plugging of old wells to prevent losses outside the casing into other underground reservoirs, and the reduction of flows from all wells to as near the amount that can actually be used as is practicable, will preserve the flow for many years. The best results can only be obtained from State-wide efforts, but local efforts will do considerable to lengthen the flow in the county, since the fall in pressure is not transmitted immediately from one part of the basin to another. It is recommended that as far as practicable, wells in the county be kept in good repair and old and unused wells be plugged. Leaky casings and poorly sealed wells not only reduce the pressure in the artesean sand but allow artesian water to escape into the glacial sands changing the character of the water in those sands and bringing in salts which might be undesirable. This is especially true of artesian wells in which the water might escape into the contact sand at the base of the glacial drift which is now and will be an important source of water for the Coteau sections of the county.

## The Second Flow

As stated before, two sands occur in the county from which artesian flows have been derived. The lower sand is not used in this county, though it is farther west. It carries hard water which will not yield alkalies when used for irrigation.

It was struck on a farm in the NE¼ of Sec. 6, T. 123 N., R. 59 W. Five wells were drilled on this farm, two of which were drilled into the second flow. The first flow was encountered at a depth of 1070 feet and the second at 1180 feet. Both wells threw a fine white sand from the second flow which choked so badly that they were abandoned. Hard water is reported at a pressure of sixty-five pounds. This would make the initial bottom pressure 575 pounds, about equal to the original pressures obtained from the upper sand. There is no way to determine whether this pressure could be obtained from the second sand now except by drilling into it. It is probable that it too has diminished, since the sand is being used farther west. The second sand offers an unused source of water to the county which may be important because of its quality and may be a reserve flow if it is impossible to maintain the head on the upper sand.

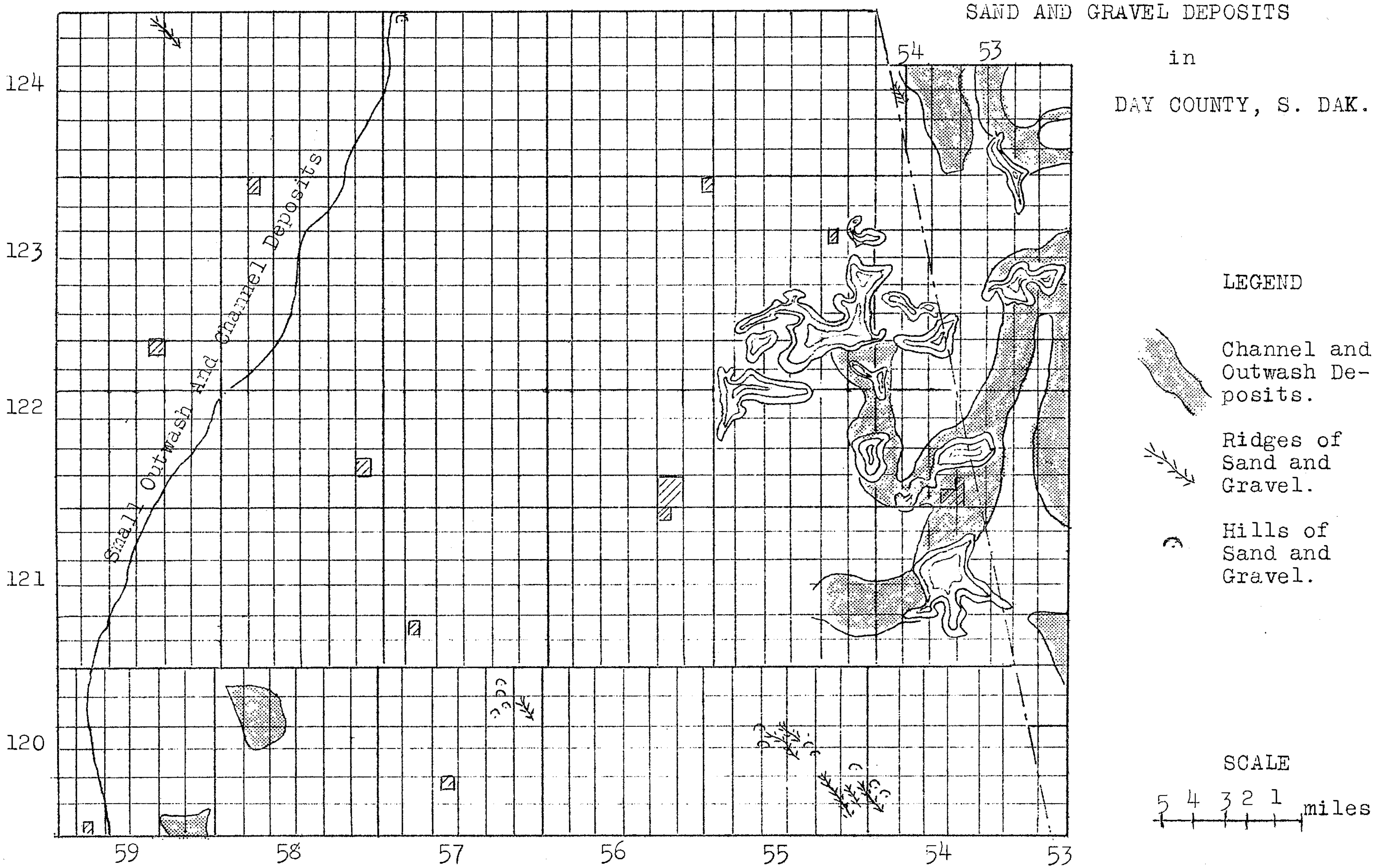
## Other Flows

There is no information available at present as to the character of the rocks underlying the second sand just described. In some regions still other sands lie beneath this lower artesian flow, and it is not beyond the realms of possibility that they may exist beneath the sand in Day County. If they do exist it is

SAND AND GRAVEL DEPOSITS

in

DAY COUNTY, S. DAK.



probable that they contain water under pressure which will rise to heights practicable to reach with a pump if they will not flow. The presence of such sands can be discovered only by deep drilling and will have to await a greater necessity than has yet arisen, as surface supplies, glacial sands, and the two artesian sands can supply abundant water to meet the present needs and those that will arise in the immediate future.

## SAND AND GRAVEL

Day County is well supplied with sand and gravel suitable for most structural purposes. The intense glacial activity caused the deposition of an abundance of these materials, and some deposits are suitable for commercial exploitation. They are well scattered, supplying material for local needs within short hauling distances of most parts of the county. For descriptive purposes they will be grouped according to origin as channel and outwash gravels, kame and esker gravels, and gravels in the drift.

### Channel and Outwash Deposits

Most of the deposits which present commercial possibilities belong to this class. Their origin has been explained under the section on Glacial Geology. As was pointed out in this section, the large channels and outwashes lie in the eastern part of the county between the Webster, Pickerel, and Waubay Moraines. The easternmost outwashes lie in the Big Sioux Valley on the east side of the Waubay Moraine and cross the county line into Grant County. The northern section is about a mile in width in Day County and extends from the east side of Enemy Swim Lake southward to the Milwaukee Railroad. A second section of this outwash lies on the county line east of the southern end of Bitter Lake and covers an area of about two and one half square miles in Day County. The Milwaukee Railroad operated a pit in this deposit on the county line a mile and a half north of the tracks. Thirty feet of sand and gravel was measured five miles north of the railroad (NW$\frac{1}{4}$ Sec. 36, T. 123 N., R. 53 W. res.). In the railroad pit fifteen to twenty feet was exposed. Like all such deposits there is considerable heterogeneity of materials, though most of the deposit is made of medium to fine gravels and medium sands. The volume was not calculated, but with about ten square miles underlain by the deposit, the cubic yardage would run into the millions.

A second large deposit is the outwash channel passing from Enemy Swim Lake through Waubay into Bitter Lake. This outwash holds an enormous volume of well sorted sands and gravels which have never been exploited commercially. The channel averages a mile in width and is filled to depths of fifteen or twenty feet with gravel, approximating a volume of 325,000,000 cubic yards of material. At the southern side of Enemy Swim, eighteen feet of gravel is exposed; a mile south in a small valley cut into the outwash, twenty feet are exposed. A mile still farther south a gravel pit was opened at the roadside exposing fifteen to twenty feet of gravel with pebbles averaging one fourth to one half inch in a matrix of clean sand. A pit has been in operation for local use at the east edge of Waubay where ten feet of gravel furnished excellent material for local building. In the vicinity of Bitter Lake, the deposit contains more sand than farther north. Road cuts and a pit just north of the lake showed medium to fine gravel and medium grained sand. Gravel pebbles average one half inch in diameter and most of them are of hard material. The sand is clean, made largely of quartz grains, and runs about thirty to forty mesh. Fifteen feet of this material is exposed in this locality. The deposit is readily accessible, close to roads and highways, and can be transported to market over good roads, highways, or railroads.

The western channel containing Waubay, Minnewasta, and Rush Lakes has much of its gravel under cover, so little detailed information can be available without more detailed investigation. The exposures lie largely about the shores of the lakes whose waves have cut into the channel. In these places typical glacial gravels and sands are exposed. Some are well sorted, but much is mixed with fine sands and silty material. A pit on the west side of the Waubay Lake basin (W$\frac{1}{4}$ cor. Sec. 18, T. 122 N., R. 55 W.) showed more than twenty feet of gravel averaging one eighth to one fourth inch and much medium grained sand. About one per cent of the deposit was made of small boulders. Very little chalk, shale, or other soft materials were found in the gravel, and this is decidedly in its favor, especially for use as concrete material. Gravel and sand of good quality are exposed about the shores of Lake Minnewasta and between Spring and Waubay Lakes, but farther south in the channel they are covered by silts and soils. Allowing four yards as an average depth of the gravels in this channel, there should be a total of about 150,000,000 cubic yards.

The extensive outwashes about the northern end of Pickerel Lake offer large amounts of materials. Eight feet of gravel is exposed at the southern end of the western outwash, and clean sand and gravel was exposed in road cuts in many places over its surface. The areas of these outwashes will warrant a large volume if the depths are over two yards, and the thin cover would make them readily accessible. These outwashes are well worth prospecting for large scale gravel or sand operation.

Smaller areas of outwash are indicated on the accompanying gravel map and are worthy of prospecting. Two of the largest lie on the highland in the southwest corner of the county in Troy (T. 120 N., R. 58 W.) and Oak Gulch (T. 120 N., R. 59 W.) townships. These areas cover two to four square miles each. The thickness of the gravels was not disclosed by pits or cuts, but it is probable that they are thin because of their position high up on the moraine and the lack of channels in which they were deposited. They are local outwashes formed by local torrents during the formation of the Bristol Moraine.

Other channel deposits occur along the base of the Coteau Escarpment in Andover township (T. 122 & 123 N., R. 59 W.). Considerable sand and some gravel indications were encountered in the road cuts, especially near the stream valleys. Some of these have been indicated on the accompanying gravel map, though it is impossible to draw boundaries with the present information. These deposits offer good prospecting. Some gravel deposits have already been opened. These are of doubtful value as commercial deposits, as they are not large or deep, but should make a good source of supply for local consumption.

## Kame and Esker Deposits

These gravels are abundantly scattered over the county in the terminal moraines which have been described. They occur as knob-like hills of gravel which in many cases are not easily distinguishable from the ordinary clay hills of the moraine and as long ridges of sand and gravel, conspicuous because of their ridge-like shape and the steepness of their sides. These have supplied much of the local demand for road gravels and for local construction. Though they are not large, they often compensate for individual size by occurring in groups which in the aggregate may yield fairly large amounts of material. A production of 10,000 yards is good for the average kame and small esker, though the latter may yield four or five times that amount.

The gravels are usually dirty and ill sorted, and in excavating most of them, clay masses interrupt the gravel and sand. The patchiness and poor sorting of the sands and gravels makes it necessary in most cases to size the material used by screening before it can be used. The chief virtue in these deposits is that they are so widely scattered through the moraines that they are readily available for road construction or other purpose where a clean, well sorted material is not essential.

One large field deserves special mention because it might be developed into a commercial proposition. This field lies ten miles south and four miles east of Webster and occupies a large portion of Wheatland township (T. 120 N., R. 55 W.). The eskers and kames lie in a belt about a mile wide and five miles long which trends northwestward from the southeast corner of the township. There are at least six large esker ridges more than a mile in length and a score or more of kame hills from which sand and gravel could be excavated. No attempt was made to measure the volume of materials which these hills contain, but a conservative estimate would have to place it well over a million cubic yards. Their scattered location makes it difficult to excavate as large a percentage of the available gravel as can be taken from a channel deposit or outwash, but the location of the material in hills and ridges simplifies the excavating and loading problems.

## CLAYS

Day County clays have never been used for commercial purposes. The glacial drift offers an abundance of clay which could be used for brick making and similar rough pottery. The channels in the James Valley Lowlands in some instances contain clays which have been washed by glacial waters until they are quite fine and free from impurities. The shales outcropping in the James Valley section of the county offer some possibilities, though they are more siliceous than ordinary clays.

The lack of cheap fuel in the vicinity does not make it likely that local clays will be able to compete with clays from abroad under present conditions. Should the opportunity arise, however, clays from Day County could be turned into good account as building material.