SOUTH DAKOTA GEOLOGICAL SURVEY
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STATE OF SOUTH DAKOTA
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GEOLOGY
of the
ESTELLINE QUADRANGLE
SOUTH DAKOTA

EXPLANATION

Qal — Alluvium
(Semistratified deposits of gravel, sand and silt; humic, brown to black; 0-20 feet thick; in stream flood plains and lakebeds.)

Qwcvo — Middle? Cary Valley Train Outwash
(Stratified deposits of brownish-gray to bluish-gray poorly-sorted fine sand to coarse gravel; unoxidized; level topography; sandy loam soil; ranges from 15-95 feet in thickness.)

Qweco — Early Cary Outwash
(Stratified brown fine sand to coarse gravel; weathered; contains abundant iron-oxide; these terrace remnants stand about 25 feet above valley floor; exposed thickness 25 feet.)

Qwce — Cary End Moraine
(Boulder-clay till consisting of olive-gray to olive-brown calcareous silt and clay with rock fragments friable; ranges up to 100 feet in thickness; rugged undrained knob and kettle topography)

Qwto — Tazewell Outwash
(Stratified poorly-sorted sand and gravel; terrace remnants; oxidized; ranges from 10-30 feet thick.)

Qwte — Tazewell End Moraine
(Boulder-clay till consisting of olive-gray to olive-brown calcareous friable to compact silt and clay with rock fragments; mostly unoxidized; gently rolling well drained topography; ranges up to 210 feet in thickness.)

Qwig — Iowan? Ground Moraine
(Boulder-clay till consisting of olive-gray to olive-brown calcareous friable to compact silt and clay with rock fragments; mostly unoxidized; ranges up to 150 feet in thickness; level and well-drained topography; calcareous loess cover up to four feet thick.)

RECENT
PLEISTOCENE
WISCONSIN
QUATERNARY

Contact
(dashed where approximately located)

Gravel Pit

x BM 1737
Bench Mark
(monument showing exact altitude above sea level)

△ Sheridan
Triangulation Station
(monument marking exact geographic location)

House, school, and church

Cemetery

Estelline Quadrangle

Geology by Fred V. Steece, 1957

Assisted by R.C. Wilson, D.G. Jorgenson, R. VonHoldt

Vertical and horizontal control surveyed from triangulation and level lines of Federal surveys

Drafted by C.F. Harris & J.H. Hoff

APPROXIMATE MEAN DECLINATION, 1958

Scale 1:62500

Vermillion, South Dakota
1958

■ Quadrangle Location

INTRODUCTION

The Estelline quadrangle is in parts of Hamlin, Deuel, and Brookings Counties in northeastern South Dakota (see Index Map, reverse side); it occupies about 215 square miles. The quadrangle lies in the north-central part of the Coteau des Prairies upland (Rothrock, 1943, map). The drainage is controlled by the Big Sioux River, and its major tributaries Stray Horse, Hidewood, and North Deer Creeks. There are no natural lakes in the quadrangle. The topography is chiefly that of nearly flat-lying to gently undulating. The average relief is 50-60 feet, ranging up to 210 feet in the northeast corner of the quadrangle.

Estelline, population 760, 1950 census and Dempster, population 150, are the only towns in the quadrangle. There are 1.8 dwellings per square mile in the area.

U. S. Highway 77 crosses the southeast corner of the quadrangle; it is supplemented by State Routes 22 and 28. In addition, nearly every section line is marked by a good gravel road. The Chicago and North Western railroad serves the area and the town of Estelline.

The climate of the area is characterized by rapid and extreme fluctuations in temperature, with long cold winters and short hot summers. The average temperature (at Watertown) is 43° F and the average precipitation is 21 inches. Agriculture is the chief industry of the area, the major crops being corn, wheat, barley, oats, alfalfa, soybeans, sorghum, flax, and potatoes. Potato-distributing and livestock-raising are also important industries.

Geologic mapping was done on air photos in the summer of 1957. Outcrop information was supplemented by hand auger borings, and the thickness of outwash deposits was determined by 23 holes drilled by jeep-mounted augers.

Thanks is due Dr. A. F. Agnew under whose supervision this work was accomplished, to Dr. M. M. Leighton whose comments were helpful, and to Dr. K. Y. Lee and M. J. Tipton for their help in field conferences. The writer wishes to thank the residents of the Estelline quadrangle for their cooperation and aid during the course of the work.

SURFICIAL DEPOSITS

The surficial deposits of the Estelline quadrangle are Pleistocene glacial drift and Recent alluvium.

Glacial Drift

Glacial drift comprises all the material transported and deposited by glacial ice of the Nebraskan, Kansan, Illinoian, and Wisconsin glacial stages of the Pleistocene Epoch. Drift includes till, outwash, and loess. Till is nonsorted, nonstratified boulder clay. Outwash is stratified sand and gravel deposits, usually unsorted. Loess is well-sorted wind blown silt and clay derived from the ablation of outwash.

The glacial drift in the Estelline quadrangle represents the Iowan (?), Tazewell, and Cary substages of the Wisconsin glacial stage.

Iowan (?) Substage

Iowan (?) till is dark olive-gray to dark olive-brown in color; it normally is calcareous but may be leached locally to a depth of several feet. The generally dark color of the fresh till is due to the lack of oxidation. Where the till is compact, however, it does exhibit iron-oxide staining on joint faces; where the till is friable, on the other hand, little or no oxidation is present except after long exposure; it weathers light tan to buff.

The average composition of the 4-8 mm. pebbles of the Iowan (?) till is 52 percent carbonate rocks, 8 percent igneous and metamorphic rocks, and 40 percent other rocks. The thickness of the Iowan (?) till ranges up to 146 feet.

The Iowan (?) till is characterized by level topography except where it forms the bluffs of the Big Sioux valley. It has a well-integrated dendritic drainage pattern developed on its surface. The till is overlain by a variable thickness of discontinuous brownish-yellow calcareous loess, which has a maximum thickness of four feet. A silt or clay-loam, brownish-black soil, with a maximum thickness of three feet is developed on the surface of the till and loess. The soil is normally leached to a depth of about 8-10 inches.

Tazewell Substage

Tazewell deposits in the quadrangle are till and outwash. The till was deposited by the westernmost advance of the Tazewell ice of the Des Moines lobe which occupied the Des Moines River valley in Iowa. The moraine thus formed is called Bemis (referred to as Cary age by Flint, 1955), from the type locality at Bemis, South Dakota about 10 miles east of Watertown. The outwash resulted from the meltwater of the ice which built the end moraine.

The till is characterized by a smooth gently rolling end moraine topography with well integrated drainage and few closed depressions. The till is dark olive-gray to dark olive-brown, calcareous, and unoxidized on fresh surfaces. It is typical boulder-clay consisting of clay and silt with minor percentages of sand and rock fragments. The till is covered sporadically with a thin yellowish-brown calcareous loess and/or silt and clay loam, brownish-black partially leached soil. The maximum thickness of the Tazewell till is about 150 feet.

The Tazewell outwash consists of valley till preserved as terrace remnants along Stray Horse and Hidewood Creeks, the Big Sioux River and a small tributary, Peg Munky Run. The Tazewell age of the deposits is based on the fact that they can be followed northeastward along the course of the streams to their source in the Bemis (Tazewell) moraine about 15 miles east of Estelline.

The Tazewell remnants range in size from one-fourth square mile to 2 square miles in area. They are composed of sand and gravel ranging in texture up to very coarse boulders. The material is ordinarily well-weathered, and contains abundant iron-oxide. In composition carbonate, and igneous and metamorphic rocks predominate over lesser percentages of other rocks. In exposed thickness these deposits average 20 feet; they stand 10-70 feet above the lower valley outwash and have a level surface.

Cary Substage

The Cary drift in this quadrangle consists of till and outwash laid down by the first two of three possible advances of the Cary ice of the James lobe which followed the James River lowland in South Dakota.

The Cary till is characterized by subdued knob and kettle end moraine topography. Undeveloped drainage is shown by the abundance of closed depressions and the absence of streams. The maximum relief of the Cary is about 40 feet.

The average composition of the till is 39 percent carbonate rocks, 10 percent igneous and metamorphic rocks, and 51 percent other rocks. The till is light and dark olive-gray to light and dark olive-brown, and weathers light-buff. It is calcareous throughout and normally is not oxidized except after prolonged exposure. The Cary till averages about 45-50 feet in thickness.

Very thin discontinuous brownish-yellow calcareous loess overlies the till. The till has a variable thickness of silt and clay-loam soil on its surface. The soil is dark brown or black in color and is usually leached near the top; it ranges up to 1½ feet in thickness but averages about six inches.

Two ages of Cary outwash are recognized in this quadrangle. Early Cary outwash is preserved as a high outwash in the southwest corner of the quadrangle immediately adjacent to the Cary end moraine from which it was derived. It joins with and is truncated by the lower Middle (?) Cary valley train outwash. The Early outwash is composed chiefly of poorly-stratified sand and medium to coarse gravel, containing minor amounts of silt and clay. Average percentages of constituents are 50 percent carbonate rocks, 30 percent igneous and metamorphic rocks, and 20 percent other rocks. The material contains considerable iron-oxide which locally serves as cement. The soil mantle on the outwash is dark-brown sandy loam about 8-12 inches thick.

The Middle (?) Cary outwash occurs as valley train deposits in the Big Sioux River valley and in the valleys of Stray Horse, Hidewood, and North Deer Creeks and in several other small tributaries. The outwash consists of sand and gravel with lesser amounts of silt and clay. It is normally unoxidized and is gray to brown in color. The material occurs in alternating coarse and fine layers which are often coarser near the source. The average composition of the Middle (?) Cary outwash is 45 percent carbonate, 43 percent igneous and metamorphic, and 12 percent other rocks. The topography of the valley train is level to gently undulating. This outwash is mantled by a variable thickness of sandy loam and silty loam soil. The soil normally is less than a foot thick, but locally may be 2½ feet thick, it is generally leached in the upper few inches. The valley train outwash ranges in thickness from 12-93 feet and averages 49 feet.

Recent Alluvium

Alluvium of Recent age occupies the flood plains of the Big Sioux River and its major tributaries. The material consists of dark semistratified to stratified gravels, sand and silt with lesser amounts of clay and humus. The alluvium ranges up to 20 feet in thickness and averages about three feet.

SUBSURFACE ROCKS

No bedrock is exposed in the quadrangle. On the basis of data obtained from well logs around the area, however, Precambrian rocks form the basement and are unconformably overlain by Cretaceous sedimentary rocks.

The Precambrian consists of Sioux Formation ("quartzite"). The Cretaceous strata are in ascending order the Dakota Group (A. F. Agnew, personal communication, May 1958), 150 feet thick; the Graneros Formation, 155 feet thick; the Greenhorn Formation, 31 feet thick; the Carlile Formation, 196 feet thick; the Niobrara Formation ("chalkstone"), 93 feet thick; and the Pierre Formation, 243 feet thick.

STRUCTURE

The structure of the subsurface rocks of the Estelline quadrangle is relatively simple. The surface of the Precambrian is uneven, probably erosional, and has a gentle slope to the northwest (Steece, 1953). The Cretaceous strata are relatively flat-lying and, as mentioned previously, lie unconformably on the basement. In places, Cretaceous rocks overlap the Precambrian.

ECONOMIC GEOLOGY

Shallow Ground Water

All the unconsolidated Pleistocene deposits in the quadrangle contain interstitial waters. The quantity and quality of water contained in the outwash exceeds that found in any of the other materials. The level at which the water is maintained in the outwash materials is the water table. This normally conforms to the topography and thus in this quadrangle it slopes generally southward with a resulting slow movement of water through the porous material from north to south.

The occurrence of ground water in the outwash is dependent on several factors, including permeability, porosity, and extent. Permeability is the ability of a material to transmit water through its interstices. In general, coarse-grained material is more permeable than fine-grained material with similiar grain arrangement. Porosity is the amount of pore space in a given material. Porosity is dependent on grain shape rather than size; thus a material may have a high degree of porosity and yet have a low permeability if the pores are not interconnected or if the openings between pores are very small. An ideal water reservoir material would have spherical grains one to two inches in diameter.

An equally important factor determining quantity of water is the extent of the deposit in which it is contained. The total area occupied by outwash deposits in the quadrangle is 54 square miles. Of this, 84 percent can be considered as potential source of shallow ground water. However, the other 26 percent is terrace remnants and since these are unconfined they do not contain large amounts of water. The average thickness of the valley train outwash is 46 feet covering an area of 29,440 acres. The average depth to water is 12 feet. Thus, there are 34 feet of saturated sand and gravel occupying a volume of 1,610,000,000 cubic yards. The average porosity of the materials is 30 percent. Thus, the valley train outwash contains 297,000 acre-feet or 98,600,000,000 gallons of water.

The average annual precipitation at Watertown is 20.9 inches (U. S. Weather Bureau). Most of this water is absorbed directly by the porous soil on the surface of the outwash, forming the major recharge for the materials. Recharge is also accomplished by run-off from surrounding uplands, by underflow or slow percolation of water in the gravels downstream, and by overflow of streams during flood periods. The main discharge or removal of water from the outwash material is through wells, underflow away from source areas, seeps and springs, transpiration by plants, and evaporation. In general, recharge exceeds discharge in this quadrangle so that underflow accounts for any excess recharge, keeping the water table annually fairly constant.

Recovery is the process by which the water level in a pumping well or a well which is influenced by a pumping well resumes its normal level after pumping has ceased. The rate of recovery depends on the permeability of the material which the well penetrates, and on the rate of recharge. In general, the recovery in the outwashes of this area is good and wells should return to normal in a short time if the recharge is normal.

The quality of water in the outwash deposits (table 1) is generally good for irrigation.

Table 1. Analyses of Water Samples from the Estelline Quadrangle

Constituent ppm / No.	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	NO_3	Cl	Fe	Hardness $CaCO_3$
7*	86	43	20	2	245	10	150	6	15	0	390
8*	122	92	50	4	405	40	290	1	33	0.1	684
9*	65	51	17	3	315	0	55	1	18	0	368
11**	92	35	24		334	0	56	12	18	0	376

7. Gillard Sween, NW¼NE¼ sec. 1, T. 112 N., R. 51 W., Brookings County.
8. Carllyle Johnson, NE¼SE¼ sec. 35, T. 113 N., R. 50 W., Deuel County.
9. R. Dykstra, SE¼SE¼ sec. 10, T. 114 N., R. 51 W., Hamlin County.
11. Estelline City Well No. 1 (NOTE: Concentrations of NO_3 in excess of 10 ppm may be harmful if used for human consumption).

*Analyzed by O. E. Olson, Station Biochemistry, South Dakota Agricultural Experiment Station, College Station, Brookings, South Dakota, 1957.

**Analyzed by Division of Sanitary Engineering, South Dakota State Department of Health, Pierre, South Dakota, 1956.

Normally till water is not satisfactory for irrigation use. Excessive concentrations of sodium, boron, sulfate, carbonate, and chloride ions are considered harmful to plant development (see Steece, 1958 for further details).

The use of outwash water for irrigation in the Estelline quadrangle is recommended with several qualifications. First, periodic analyses of irrigation water should be carried out often during the pumping season owing to higher salt concentrations by re-circulation. Second, each well should be deep enough to completely penetrate the outwash and should be located near the center of the outwash, rather than its till borders. Third, because of the porous nature of the soil on the outwash and because the outwash is relatively level, sprinkler irrigation rather than ditch irrigation would probably be more adaptable.

Deep Ground Water

Some subsurface strata yield sufficient water for most domestic purposes, but the water is generally not suitable for irrigation use because of quality and/or quantity. Water is available from the Dakota Group, the Codell sand of the Carlile Formation, the Niobrara Formation ("chalkstone") and the Sioux Formation.

Many wells in the quadrangle draw water from the till, but, as already mentioned, this is usually unsuited for irrigation.

Buried stream channels may yield domestic supplies of water. Flint, (1955, map, plate 7) has suggested the presence of several of these in the Estelline quadrangle.

Sand and Gravel

Sand and gravel deposits of the area occupy 34,560 acres. The estimated reserve of these is 2,510,000,000 cubic yards. The material is composed chiefly of carbonate and igneous and metamorphic rock fragments with less than 2 percent of silt and clay. Minor percentages of shale, chalk and clay-ironstone (limonite) are present as deleterious materials. In general, the material is good for road metal and concrete aggregate.

Clay

The tills in the area contain 60 percent silt and clay. Brick-making and ceramic industries could find an abundance of clay for their needs.

Oil and Gas

No oil or gas has been found in Eastern South Dakota. The pinchouts formed by the Cretaceous strata and the Precambrian basement may have been sites for oil accumulation in the past, and thus might be worth prospecting.

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