SOUTH DAKOTA GEOLOGICAL SURVEY

ALLEN F. AGNEW, STATE GEOLOGIST

STATE OF SOUTH DAKOTA

RALPH HERSETH, GOVERNOR

GEOLOGY
of the
WINNER QUADRANGLE
SOUTH DAKOTA

EXPLANATION

QUATERNARY

RECENT

Qal

Alluvium

(Floodplain deposits of silt, and sand in valley of present streams; maximum thickness 6 feet.)

PLEISTOCENE

Qts

Terrace Gravel or Sand

(Locally derived silt, sand, and limey gravel capping small hills; very calcareous; most large grains composed of silty calcareous nodular material. Maximum thickness 12 feet.)

UNCONFORMITY

TERTIARY

PLIOCENE

Tpa

Ash Hollow Formation

(Medium-gray to light olive-greenish, weathers light-gray, fine calcareous arkosic sandstone "mortar beds" capping buttes. Thickness 13 feet.)

Tpv / Tpa

Valentine Formation

(Medium-gray to light olive-gray poorly consolidated fine arkosic sand; local lenticular layers of light olive-greenish silty clay; maximum thickness 140 feet. Bijou facies.-- gray to greenish fine-grained opaline arkosic sandstone, very well cemented with silica; as lenses in the Valentine Formation; maximum thickness 5 feet.)

UNCONFORMITY

OLIGOCENE

Tab

Brule Formation

(Pinkish clayey silt with waxey luster on freshly broken surfaces; local very small grains of pink montmorillonite clay; approximate maximum thickness 50 feet.)

UNCONFORMITY

UPPER CRETACEOUS

PIERRE

Kpu

Upper Pierre Unit

(Dark platy marine clay-shale, calcareous in lower part; local thin layers of dark limestone and siderite in upper part, weathers to brown or orange limonite flakes; maximum thickness 398 feet.)

Contact
(dashed where approximately located)

X Gravel Pit

X BM 1972
Bench Mark
(monument showing exact altitude above sea level)

X 2275
Spot Altitude

△ WINNER
Triangulation Station
(monument marking exact geographic location)

House, School, and Church

Geology by Sam G. Collins, 1957

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

Drafted by Bruno C. Petsch, 1960

APPROXIMATE MEAN DECLINATION, 1959

Scale 1:62 500

Vermillion South Dakota
1960

Tertiary Sediments

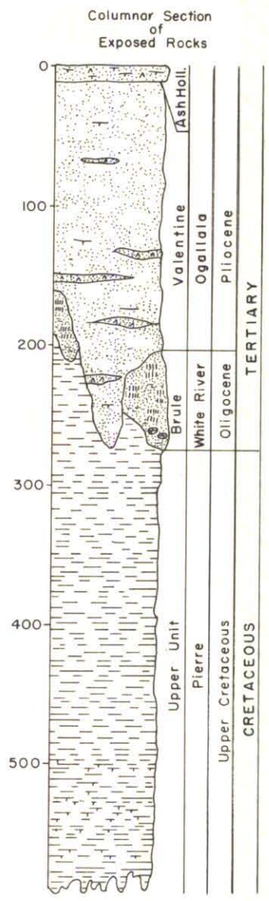
Quadrangle Location

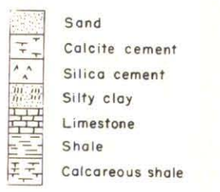
WINNER QUADRANGLE

GEOLOGY OF THE WINNER QUADRANGLE

By

Sam G. Collins





INTRODUCTION

The Winner quadrangle was mapped during the summers of 1956 and 1957 as a Master's thesis problem under the direction of Dr. A. F. Agnew, Professor of Geology at the State University of South Dakota, and State Geologist. Thanks are extended to Drs. E. P. Rothrock, R. E. Stevenson, and E. H. Shaw of the University for their cooperation and assistance in the field and laboratory, and for the equipment which they made available for the project. The field assistance of R. A. Schoon, T. J. French, P. D. Lidel, and J. C. Harksen is also gratefully acknowledged, as is the petrographic information furnished by W. H. Taft, and information concerning soils within the area furnished by Robert Springer of the U. S. Soil Conservation Service in Winner.

The quadrangle includes approximately 217 square miles of central Tripp County in south-central South Dakota. Winner, with a population of 3252 in 1950, is centrally located and is the county seat. It is the only town in the quadrangle. The southern edge of the quadrangle is about 17½ miles north of the South Dakota-Nebraska boundary.

The Winner quadrangle lies mostly in the Missouri Plateau, and partly in the High Plains subdivisions of the Great Plains physiographic province. Most of the area is characterized by rolling plains of relatively low relief, developed on the marine rocks of the Pierre Formation. Toward the southern border of the quadrangle the surface rises into butte-and-mesa topography typical of the High Plains, developed on the Brule and Ogallala sediments.

The quadrangle is drained by intermittent northward-flowing streams. The major streams are Dog Ear Creek and its tributary Big Hollow Creek in the western half of the quadrangle, and Thunder Creek in the eastern part. The streams are tributary to the White River, which they enter about 13 miles north of the quadrangle. They have an average gradient within the quadrangle of 15 to 20 feet per mile.

Local relief is generally less than 100 feet, but at the Battelyoun Buttes the surface altitude of 2310 feet is 350 feet above the surrounding plain. Maximum relief within the quadrangle is 582 feet. Altitudes above sea level range from 1872 feet in the valley of Thunder Creek where it leaves the quadrangle, to 2454 feet at the top of Dog Ear Butte.

The climate is typical of the temperate High Plains. Temperatures range from 38 degrees below zero to 114 degrees Fahrenheit, the annual mean being close to 50 degrees. Annual precipitation ranges from 11 to 29 inches, the average being about 18 inches. Despite the relatively small amount of rainfall, small-grain farms prosper throughout most of the area, as the greatest part of the moisture comes during the critical early months of the growing season. Strong winds are the rule, prevailing from the south and southwest during spring and summer, and from the north and northwest in fall and winter. All weather data are taken from the U. S. Weather Bureau Station at Winner.

The Winner quadrangle is primarily a farming area, although considerable land is also devoted to grazing, particularly in the uplands and areas of high relief. Rural population is relatively sparse, about one family per 0.9 square miles.

The area is served by only one hard-surface road, U. S. Highway 18-183, which trends westward and southeastward from Winner. Gravel roads connect Winner with towns to the north and southwest. An extensive network of graded and otherwise improved rural roads, some gravelled for short distances, provides ready access to almost all farm homes. Unsurfaced roads on the gumbo clay soils of the Pierre Formation are completely impassable for ordinary vehicles in wet weather. Roads on the sandy soil of the Valentine Formation are hazardous when wet, but are generally passable except under extreme conditions.

The Chicago and Northwestern Railroad links Winner with towns to the west and southeast.

There are no natural lakes in the area, but a multitude of small stock dams have been constructed. As the Pierre shale, which is the surface rock over most of the area, is quite impermeable, the runoff at times of heavy rainfall fills the reservoirs rapidly, and most of them retain water throughout the year.

EXPOSED ROCKS

The Cretaceous Pierre Formation, a thick marine shale, underlies the entire quadrangle and crops out at lower altitudes over most of the northern four-fifths of the area. At higher altitudes, particularly in the southern part of the quadrangle, the Pierre is overlain mostly by the continental deposits of the Oligocene White River Group and the Pliocene Ogallala Group. Quaternary deposits of locally derived sand and gravel occur along stream valleys, and as caps on small topographic prominences.

Cretaceous System

Pierre Formation, Meek and Hayden, 1862

The Pierre Formation (Kpu) was named from exposures near Fort Pierre, South Dakota, about 70 miles north of Winner. It underlies the entire Winner quadrangle, and is exposed at the surface over most of the area. Owing to the rapidity with which the formation is weathered and eroded when exposed, the topography developed upon it in this area is gently rolling or nearly flat, and a deep soil has been developed at the surface. Very few outcrops of undisturbed rock occur.

Exposures along the bed of Thunder Creek, in Secs. 32 and 33, T. 102 N., R. 75 W., about six miles downstream (north) of the northern boundary of the quadrangle, exhibit a lithology identifiable as the Virgin Creek Member of Searight (1937). This unit was not found at any place within the Winner quadrangle. As the attitude of the bedrock in the surrounding area is horizontal or very slightly southward-dipping, and as lithologic characteristics of the Pierre members exposed in the quadrangle made it difficult to differentiate the Mobridge and Elk Butte Members of Searight (1937), the Pierre of the Winner quadrangle is mapped as the Upper Pierre unit of Agnew (1957).

The lithologic character of the Pierre undergoes a gradual change westward from that described by Searight (1937) in his study along the valley of the Missouri River. Agnew (1957), Schoon (1958), and Collins (1958) report difficulty in distinguishing the Mobridge from the Elk Butte in areas adjacent to the Winner quadrangle and farther west. This area evidently lies in the transitional zone where the two members begin to lose their identity toward the west. Two lithologic units were found in the quadrangle, the upper resembling the Elk Butte and the lower corresponding to the Mobridge, but it was impossible to define the boundary between the two except at one exposure in a gully draining the northern side of the Trudell Hills. Here, at the east side of Sec. 12, T. 100 N., R. 77 W., the contact is gradational; the calcareous blocky shale of the Mobridge gives way upward to increasingly thick tongues of fissile noncalcareous shale characteristic of the Elk Butte Member. The transition zone is at least 20 feet thick. Tongues of the calcareous shale undoubtedly occur above the sequence exposed here, as the soil above is calcareous, but slumped material and soil cover the bedrock.

A slightly steeper topography is developed on the Elk Butte than on the Mobridge, probably owing to the fact that the calcite content of the latter makes it subject to chemical as well as mechanical weathering. However, the upward change in slope is gradual through the contact zone, and cannot be used as a distinguishing characteristic in mapping. Although no differentiation was made between the Mobridge and Elk Butte in mapping, owing to the difficulties mentioned above, the lithology of the units will be discussed separately.

Mobridge Member, Searight, 1957.--The Mobridge Member was named from exposures near Mobridge, South Dakota, about 150 miles north of Winner. In the Winner quadrangle it crops out extensively at the lower altitudes. The Mobridge is a blocky calcareous slightly bentonitic medium-gray or dark-gray marine clay-shale that splits easily along the bedding. The shale commonly shows tiny white specks of calcareous material on freshly broken surfaces, particularly where it has undergone slight weathering. These specks appear to be the remains of micro-organisms that were partly dissolved or crushed, and then enlarged by calcareous growth around these nuclei. The shale weathers buff or light yellowish-gray, and breaks down readily to a thick layer of dark structureless gumbo. Very little concretionary material is present, although discontinuous layers of shaley chalk or soft limestone up to about an inch thick are common. No fossils were found in the Winner area, although microfossils and cephalopods are reported from equivalent stratigraphic intervals in nearby areas (Schoon, 1958; Agnew, 1957). Approximately 130 feet of the Mobridge Member is exposed in the Winner quadrangle.

Elk Butte Member, Searight, 1937.--The Elk Butte Member was named from exposures at Rattlesnake Butte, about 165 miles north of Winner in Corson County, South Dakota. In the Winner quadrangle the upper limit of the Elk Butte is the disconformable contact with the overlying Tertiary sediments. The lower limit of the Elk Butte is gradational into the underlying Mobridge, and exposures in the lower part of the member are generally more or less calcareous. The upper part of the Elk Butte is a non-calcareous medium-gray finely laminar marine clay-shale, non-bloating, which weathers to fine sub-metallic gray polygonal flakes. Some exposures contain thin (one inch or less) layers of concretionary ironstone material. In the highest exposures these commonly weather out as hard dark-brown or black platy fragments about half an inch thick and three inches across. The dark color may indicate a small amount of manganese. In the lower altitudes, the fragments more commonly appear on the surface as a thin scatter of brown or orange-brown limonitic flakes about an inch across and one to three-tenths of an inch thick. A heavy brown to black gumbo soil is developed on the shale where the slope angle is small. No cone-in-cone limestones, characteristic of the Elk Butte in other areas, were found in place, but it is relatively certain that these are present, as poorly rounded fragments of the material were found in gravel deposits derived locally from the Elk Butte Member.

A zone of deep chemical weathering (Interior Formation of Ward, 1926; Interior paleosol of Schultz and Stout, 1955) commonly characterizes the surface of disconformity above the Elk Butte in surrounding areas (Agnew, 1957; Stevenson, 1958b; Schoon, 1958; Collins, 1958). This weathered zone is present immediately below the Tertiary rocks in some of the exposures in the southern part of the Winner quadrangle, but was not found in the Colome Hills here in the southern part of the quadrangle, or in the Battelyoun Buttes of Trudell Hills in the northern part of the area.

Thicknesses of the Elk Butte Member, computed from the single Mobridge contact established in the area, range from 203 to 268 feet. No fossils were found.

Tertiary System

The Tertiary rock units exposed in the Winner quadrangle are the Oligocene Brule Formation, which fills topographic low areas in the post-Cretaceous disconformable surface in the southern part of the area; the Brule is in turn disconformably overlain by the Pliocene Ogallala Group, which forms the sandy upland plain and buttes along the southern border of the quadrangle. Both units consist of continental deposits of fluviatile and lacustrine origin, derived from the west.

Oligocene Series

Brule Formation, Darton, 1899.--The Brule Formation (Tob), named for the Brule Indians of southwestern South Dakota, is the only representative of the White River Group that was mapped in the Winner quadrangle. About forty miles to the northwest, in the White River quadrangle both the Brule and the underlying Chadron Formation were recognized, although the Chadron was not differentiated in mapping (Agnew, 1957). As much as fifteen feet of sediments lithologically similar to the Chadron Formation were also described in the Keyapaha quadrangle (Schoon, Sevon, 1958), which adjoins the Winner on the southwest, and in the Witten quadrangle (Schoon, 1958), which adjoins the Winner on the west. The Chadron was not differentiated in mapping in those areas. In the Wewela quadrangle (Collins, 1958), which joins the Winner on the south, and in the Gregory and Dallas quadrangles (Stevenson, 1958b; 1959) to the southeast, no Chadron is reported.

Paleontologic evidence characteristic of the Chadron was not found in the Winner area, and lithologic characteristics of the Chadron are either absent or so poorly developed as to escape notice. Consequently, all the beds in the Winner quadrangle above the Cretaceous and below the Pliocene that are correlated with the Oligocene are arbitrarily assigned to the Brule Formation.

The Brule is disconformable both with the Cretaceous below and the Pliocene above. The formation is discontinuous in the Winner area, being preserved only in low parts of the disconformity surface, where it was not removed by erosion during Miocene time. The Brule is fairly consistently an unconsolidated pink waxy non-calcareous bentonitic clay or clayey silt containing little cementing material of any kind. A scatter of small rounded silica-cemented white nodules, normally less than half an inch in diameter, generally weathers from the silt or clay on slopes.

A pink mineral that is common in the Brule and is possibly responsible for the characteristic pinkish tint of the formation, was collected from exposures in Sec. 4, T. 98 N., R. 77 W. The mineral appears in the silt as small grains (3 mm or less in diameter) with a soapy or waxy texture, almost greasy feeling, and an apparent hardness of one or less (Mohs' scale). As the mineral appears to be intergrown in the pore spaces of the silt, it is assumed to be later than the silt in origin. X-ray diffraction analysis determined the mineral to be montmorillonite, only slightly different in composition from that commonly found in bentonites.

The Brule was not observed in the Battelyoun Buttes or Trudell Hills, but appears with some regularity in the southern part of the quadrangle. No identifiable fossils were found, although chips and fragments of vertebrate bones and teeth appear commonly in alluvial deposits derived from Brule sediments.

A thickness of 31 feet of Brule was measured in the Colome Hills, and near the southwestern corner of Sec. 34, T. 98 N., R. 77 W. the drill penetrated 41 feet of the pink silt and clay. About ten feet of the unit probably occurs above the top of this hole, but slumped surficial material prevented accurate measurement. A maximum thickness of about 50 feet is probably present in the area.

Pliocene Series

Ogallala Group, Darton, 1898.--The Ogallala Group was named from exposures near Ogallala Station in western Nebraska (about 180 miles southwest of the Winner quadrangle). It is represented in the Winner area by the Valentine Formation, the Ash Hollow Formation, and the Bijou facies.

Valentine Formation, (Barbour and Cook), 1917.--The Valentine Formation (Tpv), named from exposures east of the town of Valentine, Nebraska (about 50 miles southwest of Winner), lies on the Pierre and Brule Formations; it fills depressions in the post-Oligocene surface and covers all but the highest occurrences of the older formations. The upper limit of the Valentine is its conformable contact with the overlying Ash Hollow Formation.

Good exposures of the Valentine are almost impossible to locate, owing to the friability of its very poorly consolidated sands and silts. The formation is extremely susceptible to erosion, and a flat topography with poor drainage is developed upon it. The Valentine consists mostly of very poorly cemented light olive-greenish clayey arkosic sands and silts, mostly non-calcareous but locally very calcareous, which weather light-brownish or tan. Much volcanic ash is included throughout (for detailed petrographic analysis see Taft, 1958). Thin layers of greenish clayey silt, generally not more than a few inches thick, occur locally. Small greenish or light-gray nodular concretions (half an inch or less in diameter) are present locally in the sand. Irregular lentils and isolated boulders of the Bijou siliceous sandstone facies are also present. The lower part of the Valentine at Triangulation Station "Winner" is typical in composition; it is highly calcareous and contains many white or light-gray oblate-spherical limestone concretions, some as large as two feet across. The position of the contact with the underlying Brule at this locality is uncertain. This exposure probably represents a channel or depression in the post-Oligocene surface, which was filled with locally derived material rather than typical Valentine sand.

No identifiable fossils were found in the Winner area, although fragments of vertebrate bones were observed at several localities. The thickness of the Valentine in the neighborhood of Dog Ear Butte is about 140 feet. The relief on the disconformable lower contact is as great as 96 feet within the quadrangle; this indicates that a thickness of nearly 235 feet may once have been present at the Colome Hills.

Ash Hollow Formation, Engelmann, 1878.--The Ash Hollow Formation was named from exposures in Ash Hollow Canyon, near Lewellen, Nebraska (about 185 miles southwest of Winner). The Ash Hollow extends into the Winner quadrangle at only three localities along the southern border, where it serves as the cap-rock of outliers such as the prominent landmark, Dog Ear Butte. The "mortar beds" of the formation are fairly resistant to erosion, and stand out as a sharp escarpment above the steep slopes developed on the more easily eroded Valentine Formation below. The Ash Hollow consists mostly of light olive-grayish fine ashy or tuffaceous arkosic silty sandstone, unevenly cemented by both calcite and silica to a plaster-like caliche-sandstone that weathers to a succession of light-gray irregular pitted ledges containing "boxwork" strings of silicified plant remains. These ledges are several inches to several feet thick. At Dog Ear Butte several layers of partly silicified silty clay occur near the bottom of the exposure, grading into the sandstone without a clear contact. The largest layer is more than a foot thick.

No fossils were found in the few "mortar beds" that crop out in the Winner area, although collections of Early Pliocene vertebrate remains and Celtis seeds have been made in adjacent quadrangles where exposures are more extensive. About 13 feet of Ash Hollow is present in the Winner area.

Bijou facies (Stevenson, 1953).--The Bijou facies was named as a formation from exposures in the Bijou Hills (about 40 miles east-northeast of Winner). The Bijou as redefined by Stevenson (1958a) contains only the siliceous sandstone layers of the original description. In the Winner quadrangle it is a facies of the Valentine Formation, and becomes a mappable unit at the surface only where erosion has stripped off the overlying sediments. The Bijou quartzitic sandstone is very resistant to erosion, and small sharply defined mesas and topographic highs are developed. The sandstone occurs as discontinuous lenses of considerable lateral extent, and as isolated masses scattered widely through the Valentine sands. It is mapped only where it exists in sufficient amounts to exert a significant influence on the topography. The Battelyoun Buttes, Colome Hills, and Trudell Hills are typical high areas capped by Bijou layers. An abrupt escarpment extends eastward and westward from Triangulation Station "Winner", where the Bijou occurs more extensively than in any other locality in the quadrangle.

The Bijou sandstone consists of the arkosic sands of the Valentine Formation, very well indurated by a greenish opaline cementing material. The rock appears in the field as a greenish fine-grained very hard dense quartzitic sandstone, locally well cross-bedded; it bleaches very light-gray on weathering, and shatters to large conchoidal fragments. Gravel and clay-pebbles occur in the sandstone elsewhere (Stevenson, 1953), but particles larger than sand-size are uncommon in the Winner area. The Bijou appears most commonly in the lower part of the Valentine Formation, but is not restricted to any one zone. Continuous ledges of the siliceous sandstone as much as five feet thick are found in the Battelyoun Buttes.

SURFICIAL DEPOSITS

All the units exposed in the Winner area are more or less subject to wind erosion, and thin deposits of loess or windblown sand are common. These deposits are nowhere extensive enough to have geologic significance, and thus none were mapped.

Small deposits of locally derived dirty Quaternary Terrace Gravel (Qtg) and sand cap drainage divides from the topographic level of the Tertiary sediments downward and northward. The altitude of the deposits decreases regularly northward at about 20 feet per mile. In the southern part of the area the composition is mostly limey and siliceous nodular material, with some sandstone fragments derived from the Brule and Ogallala. Northward, shale, limestone fragments, and limonite chips derived from the Pierre Formation become increasingly important constituents. A great deal of calcareous material is present throughout. The material is very poorly sorted, containing particles from clay size up to as much as five inches across. The low degree of sorting and large maximum particle size indicate turbulent depositional conditions. The material was probably laid down during times of abundant rainfall in the Pleistocene epoch, as flood-stage terraces along streams that followed more or less the same drainage pattern which exists today. Subsequent lowering of the surrounding more easily-eroded rock has left these terraces in their present high topographic position. One large herbivore tooth was found in a gravel deposit in Sec. 26, T. 99 N., R. 77 W. It has not yet been definitely identified, but it probably represents a Pleistocene horse (R. E. Stevenson, personal communication). Thicknesses of the terrace deposits range from a few inches to as much as 12 feet in the Winner quadrangle.

In several localities the terrace deposits have been mapped as Quaternary Terrace Sand (Qts). This material is identical to that mapped as "Qtg" except that it contains practically no particles larger than sand-size.

Most streams in the Winner quadrangle lack floodplains extensive enough to warrant mapping. Two localities contain material mapped as Quaternary Alluvium (Qal); the material is mostly unconsolidated sand and silt derived from the Tertiary rock units, but some clay and shale from the Pierre Formation is also included. The deposits range up to six feet in thickness.

STRUCTURAL GEOLOGY

No horizon useful as a structural datum appears in the very nearly horizontal beds exposed at the surface in the Winner area. However, electric logs from five deep wells drilled nearby (General Crude #1 Straka to the northeast, #1 Vogt and #1 Assman to the west, #1 Rural Credit and #1 Shippy, south and southeast of the area, respectively), yielded generalized structural data as summarized below.

Datum Surface	Average Dip	Direction of Dip
Top of Precambrian	13 ft per mi	S. 70° W.
Top of Greenhorn Formation	5 ft per mi	S. 88° W.
Top of Niobrara Formation	1.5 ft per mi	S. 42° W.
Top of Virgin Creek Formation	0.5 ft per mi	S. 88° W.

Dips are slight, as the Winner quadrangle lies on the broad, tectonically stable trans-continental arch that separates the Williston Basin on the north from the Central Nebraska Basin to the south.

ECONOMIC GEOLOGY

Ground water, sand and gravel, and sandstone are the only mineral resources exploited in the quadrangle, although clay materials, oil and gas, and uranium minerals may be potential economic deposits there.

Ground Water

Shallow wells furnish sufficient water for household and general farm use throughout the Winner quadrangle. Wells drilled into the Pierre shale generally have a limited rate of flow, none exceeding a few gallons per minute, and the water is generally very hard. Sulfate and iron content are rather high in most of these wells, and in some cases the high content of dissolved solids makes the water unfit for human consumption, and of only limited use for livestock. The Brule Formation furnishes relatively soft water with low sulfate and carbonate, in amounts adequate for general farm use. The sands of the Valentine Formation are the most reliable source of soft water. The municipalities of Colome (just southeast of the quadrangle) and Winner both obtain their water supplies from wells penetrating the Valentine. The Winner city wells are in the SW¼ sec. 33, T. 98 N., R. 76 W., and the Colome wells are in the SE¼ sec. 31, T. 98 N., R. 76 W. Shallow wells in some of the Quaternary deposits also yield good-quality water, though in variable quantity. As these deposits are all very calcareous, water taken from them is generally high in carbonate. Partial chemical analyses of water samples taken from typical wells in the quadrangle are summarized below (Table 1).

Sand and Gravel

Most of the terrace deposits contain gravel of fairly good quality for use as sub-base or low-grade surfacing material, in road construction. The deposits have been developed at several locations, where gravel has been removed for use in local road-work. All the deposits contain too much calcareous silt and soft pebbles to be useful as concrete aggregate.

The Valentine Formation contains a clean plaster sand, although it is too fine-grained for concrete and general construction.

Sandstone

The Bijou facies contains sandstone of a very durable character, similar in structural properties to the widely known Sioux quartzite. The Bijou is an excellent building stone, is used as rip-rap on earth-filled dams, and large quantities are crushed for concrete and bituminous aggregate in construction work and road-surfacing. The Bijou is not currently being quarried in the Winner quadrangle, although a deposit in Sec. 7, T. 98 N., R. 75 W. (Colome Hills) has been worked in recent years. Other significant deposits occur as the caprock at Battelyoun Butte, and also in the southern part of the quadrangle.

Other Resources

Clay materials possibly suitable for brick manufacture are plentiful in the Pierre and Brule Formation, but have not been developed.

Oil, gas, and uranium may possibly occur within the area, as they are found elsewhere in the Great Plains in the rock units represented here.

Table 1.--Water Analysis from Selected Wells in the Winner Quadrangle

Well Location	Source Unit	parts per million Fe	Mg	Na	K	Ca	SO_4	Cl	NO_3	Total Solids	Hardness as $CaCO_3$	Spec. Conduc. (micromhos)
Sec. 14, T. 100 N., R. 76 W.	Kpm	.1	184	423	22	488	2400	40	1	3010	1980	4300
Sec. 35, T. 100 N., R. 77 W.	Kpm	0	94	535	13	524	2150	153	100	3460	1690	4350
Sec. 34, T. 100 N., R. 77 W.	Kpm	0	73	300	13	206	990	55	3	1310	822	2590
Sec. 33, T. 98 N., R. 77 W.	Tob	0	5	9	9	128	30	28	40	630	341	900
Sec. 33, T. 98 N., R. 76 W.	Tpv	0	7	8	13	72	15	10	6	350	209	500
Sec. 17, T. 98 N., R. 77 W.	Qts	0	7	60	14	49	23	5	1	424	156	605

Analyses by Dr. O. E. Olson, Station Biochemist, S. Dak. State College, Brookings, 1958.

REFERENCES CITED

Agnew, A. F., 1957, Geology of the White River Quadrangle: S. Dak. State Geol. Survey, map and text.

Collins, S. G., 1958, Geology of the Wewela Quadrangle: S. Dak. State Geol. Survey, map and text.

Schoon, R. A., 1958, Geology of the Witten Quadrangle: S. Dak. State Geol. Survey, map and text.

_____, and Sevon, W. D., 1958, Geology of the Keyapaha Quadrangle: S. Dak. State Geol. Survey, map and text.

Schultz, C. B., and Stout, T. M., 1955, Classification of Oligocene Sediments in Nebraska: Bull. Univ. of Nebr. State Museum, v. 4, no. 2, p. 34-44.

Searight, W. V., 1937, Lithologic Stratigraphy of the Pierre Formation of the Missouri Valley in South Dakota: S. Dak. State Geol. Survey, Rept. Invest. 27, 63 p.

Stevenson, R. E., 1958a, Revision and Interpretation of the Bijou Formation: S. Dak. Acad. Sci. Proc. 1957, v. 36, p. 134-138.

_____, 1958b, Geology of the Gregory Quadrangle: S. Dak. State Geol. Survey, map and text.

_____, 1959, Geology of the Dallas Quadrangle: S. Dak. State Geol. Survey, map and text.

Taft, W. H., (1958), Studies of the Ogallala Sands in South-Central South Dakota: Unpubl. M. A. thesis, State University of South Dakota, Vermillion.

Ward, Freeman, 1926, The Position of the Interior Formation: Am. Jour. Sci., 5th ser., v. 11, p. 350-2.