SOUTH DAKOTA GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

STATE OF SOUTH DAKOTA
Frank L. Farrar, Governor

GEOLOGY of the ZEONA QUADRANGLE SOUTH DAKOTA

EXPLANATION

RECENT

Qal | Qal_1 — Alluvium

(Floodplain deposits of silt, sand, and gravel in present stream valleys. Qal, is an older alluvium deposit approximately 30 feet above the present stream channel; Qal is the youngest alluvium lying within 10 to 15 feet of the present stream channel.)

Qds — Dune sand

(Dune sand deposits located along the north fork of the Moreau River. Generally overlying older alluvium and older units.)

PLEISTOCENE

Qtu | Qtm | Qtl — Terrace Deposits

(Terrace deposits of sand and gravel size fragments of conglomerate, iron-manganese concretions, chert, and quartz. Poorly sorted throughout. Qtu is situated along the major stream divides, approximately 140 feet above the stream channel; Qtm approximately 90 feet above the stream channel; Qtl approximately 50 feet above the stream channel.)

UPPER CRETACEOUS

Kh — Hell Creek Formation

(Brown and red carbonaceous shales, brown and gray "salt and pepper" sandstones and occasional lignite, manganese, and iron concretions. Red carbonaceous shale 2 to 10 feet thick at base. About 350 feet thick.)

Kf — Fox Hills Formation

(Upper portion is gray and tan, fine-grained massive sandstone and graywacke with marcasite and iron claystone pisolites, calcareous concretions and carbonaceous material, 5 to 20 feet thick. Lower portion is composed of thin beds of alternating sandstone and shale, sandstone, gray, fine-grained, contains carbonaceous material, shale, gray and black; 2 foot coal bed in Sec. 28, T. 14 N., R. 11 E., 5 to 25 feet thick.)

QUATERNARY | PLEISTOCENE | RECENT | CRETACEOUS | UPPER CRETACEOUS

Contact line (dashed where approximately located)

2737 — Elevation above sea level

△ MUD 3051 — Triangulation Station

20° — Dip and Strike

U/D — U=upthrow, D=downthrow

House or building

School

Cemetery

Church

Oil Test — Mule Creek No. 41-33 State

Geology by Rene E. Fournier, 1965
Assisted by D. Emmett Faulkner

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

Drafted by D. W. Johnson, 1967

Approximate Mean Declination, 1962 — 14° 00' — True North — Magnetic North

Scale 1:62500

1 ½ 0 ½ 1 2 3 4 Miles

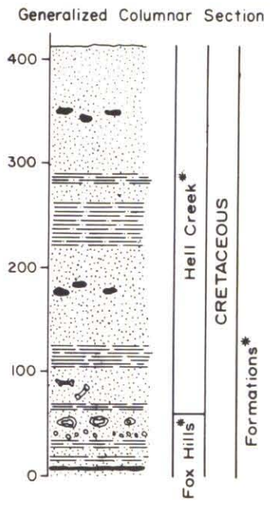
Vermillion, South Dakota
1970

ZEONA QUADRANGLE SOUTH DAKOTA

ZEONA QUADRANGLE

GEOLOGY OF THE ZEONA QUADRANGLE

by
Rene E. Fournier



INTRODUCTION

The Zeona quadrangle was mapped during the summer and autumn of 1965 under the direction of State Geologist Duncan J. McGregor. The mapping of this area is part of the South Dakota Geological Survey's continuing program of mapping and exploring the mineral resources of the State.

Acknowledgments

Appreciation for assistance in the field is expressed to D. Emmet Faulkner. Merlin Tipton and Earl J. Cox of the South Dakota Geological Survey were very helpful in orientation and advice in field and administrative matters. T. J. French offered valuable advice about stratigraphic relationships as did Robert E. Stevenson and Alan U. Lange. Robert Larimer and John Moore determined elevations throughout the quadrangle.

Special appreciation is extended to the ranchers of the Zeona and Imogene communities for their interest and cooperation.

Location and Topography

The Zeona quadrangle is located in portions of Meade, Harding, Butte, and Perkins Counties of northwestern South Dakota. It includes about five square miles of southeastern Harding County, 30 square miles of northwestern Butte County, 25 square miles of northwestern Meade County and 150 square miles of southwestern Perkins County. The quadrangle lies approximately 50 miles northeast of Belle Fourche and 180 miles northwest of Pierre.

The Zeona quadrangle lies within the Cretaceous Tableland subdivision of the Missouri Plateau division of the Great Plains physiographic province. Topography is composed of steeply rolling hills and badlands in the southern third and the northeastern quarter of the mapped area. Smooth, low hills characterize the northwestern two-thirds of the quadrangle; small, flat terraces occur along the South and North Forks of the Moreau River; several prominent buttes occur in the southwest area. Small isolated buttes are present in sec. 1, T. 13 N., R. 9 E., and sec. 10, T. 14 N., R. 11 E. The highest elevation, 3,051 feet, occurs on Mud Butte in sec. 10, T. 12 N., R. 10 E. The lowest elevation, 2,510 feet, is where the Moreau River crosses the eastern boundary of the quadrangle. Maximum relief is 541 feet and local relief exceeds 50 feet in places.

Drainage in the Zeona quadrangle is accomplished by three major streams; the North Fork of the Moreau River, the South Fork of the Moreau River, the Moreau River, and in the extreme southeast portion the tributaries of Sulfur Creek system.

Moreau River carries water most of the year, but data concerning the number of days water is carried in the North and South Forks is lacking (USGS, 1963). The gradient of the Moreau River is about 3.4 feet per mile, the gradient of the North Fork is about 7.7 feet per mile and that of the South Fork is 4.3 feet per mile. The North Fork originates in the West Short Pine Hills area about 35 miles to the northwest, and the South Fork originates near the Montana-South Dakota border, approximately 75 miles to the west. Available records at the Bixby, South Dakota gaging station 10 miles downstream indicate that the greatest flow occurs during June and the least flow occurs in January. In June, 1963, the maximum discharge was 4,390 cfs and the maximum gage height was 9.26 feet (USGS, 1963).

The North and South Forks of the Moreau River are strikingly different in the shape of their channels and valleys. The South Fork stream channel has a meander wavelength of approximately 1 mile, while the wavelength of the channel meanders in the North Fork are about 2 to 2½ miles. Valleys also differ in wavelength as the South Fork has a valley meander wavelength of about 3 miles and the North Fork has little or none. Examination of aerial photographs of the North Fork of the Moreau suggest that a braided stream pattern is developing in the present stream channel. Such development is to be expected because the North Fork drains highlands to the west and would tend to drop its load and become aggrading as it nears the confluence with the slower South Fork.

Terrace remnants are found at three levels along the South and North Forks of the Moreau and the Moreau, indicating that these streams once flowed at a higher level and are at the present time degrading. The higher terraces are recognized by the presence of small deposits of stream gravels, and the lowest terrace is recognized by the presence of broad, flat surfaces. The lower level terraces consist either of bedrock or alluvial deposits. In sec. 26, T. 14 N., R. 10 E., the alluvium is 20 feet thick on the north side of the North Fork. In sec. 30, T. 13 N., R. 10 E., the alluvium reaches a thickness of 30 feet along the south side of the South Fork and has a 5-foot thick gravel unit 20 feet above the base of the deposit.

Valley walls along the Moreau and the South Fork are generally steep because the streams have cut into the valley wall and left cut banks, but the valley walls along the North Fork are gentle and rolling with an occasional cut bank. As a result, the floodplains along the Moreau and the South Fork are narrow while the floodplain along the North Fork is broad. In general the floodplain along the South Fork does not exceed one-fourth mile in width, along the Moreau is about one-half mile, and along the North Fork is about one-half to three-fourths of a mile wide.

Floodplains and terraces were delineated on the geologic map on the basis of elevation and lithology. Two levels of floodplain material have been mapped along the stream channels. The higher level alluvial deposits are older alluvium, and floodplain material adjacent to the present stream channel is recent alluvium. Three terrace levels present above the level of the older alluvium have also been mapped. The total impression of the topography along the major streams is similar to a broad staircase because there are five distinct levels or flats above the present river channel. The highest level is approximately 2,800 feet above sea level and the stream channel is approximately 200 feet below this level. Adequate topographic coverage is not available for the mapped area, thus the precise levels of the terraces are not known.

There are several tributaries to the three streams discussed above; Trail Creek, Sheep Creek, and two unnamed creeks. Sheep Creek enters the quadrangle in the northwest corner and joins the North Fork of the Moreau. Sheep Creek is about 15 miles long and begins in the Sheep Mountain area to the northwest of the quadrangle. It has a relatively steep gradient of twenty feet per mile. There is a well-developed terrace along its length. This terrace coalesces with the lowest terrace level along the North Fork of the Moreau. Large quantities of gravel are present in the terrace and in the alluvial fill of the terrace.

Trail Creek enters the South Fork from the northwest, but it is relatively short and does not drain a large area. There are no terraces associated with this stream. A large unnamed intermittent stream drains the southeast area of the quadrangle and enters the South Fork near its confluence with the North Fork. Typical badland topography is well developed in its drainage area.

Sand dunes occur along both sides of the North Fork of the Moreau and are well defined on the aerial photographs because of their north-south alignment. The dunes are stabilized by a thin growth of prairie grass, but in some areas large blowouts are apparent.

Climate

The climate in the quadrangle is characterized as semi-arid and subject to abrupt temperature changes during the fall and spring. The area may experience severe blizzards in the winter and relative drought in the summer.

Culture

The Zeona quadrangle lies in a sparsely populated area of South Dakota. The highest concentration of people is at the hamlet of Mud Butte, where 10 people live. A store and church are the dominant structures in the hamlet of Zeona 15 miles north of Mud Butte. Approximately 100 people live on ranches in the surrounding country.

U. S. Highway 212, the only paved road in the quadrangle, is in the southern portion of the mapped area. This highway connects Mud Butte with Newell, 30 miles to the southwest, and Faith, 45 miles to the east. An improved, graveled county road extends north from Mud Butte to Zeona. Several unimproved county roads cross the mapped area and a number of fire lanes and trails aid in accessibility. However, the unpaved roads become impassible in inclement weather.

EXPOSED SEDIMENTARY ROCKS

The exposed sedimentary rocks in the Zeona quadrangle range in age from late Cretaceous to Recent. The late Cretaceous rocks are the only consolidated sedimentary rocks exposed in the mapped area. The succession of late Cretaceous rocks represents various environments of deposition ranging from fluviatile and lacustrine to estuarial, lagoonal and marine. The Fox Hills Formation of the upper Montana Group of late Cretaceous age and the Hell Creek Formation of late Cretaceous age are present. Gravel, alluvium, and sand dune of Pleistocene and Recent age constitute the unconsolidated sedimentary rocks.

Fox Hills Formation, Meek and Hayden, 1861*

The Fox Hills Formation was named for exposures of marine sandstones and shales on the eastern end of the divide known as Fox Hills between the Cheyenne and Moreau Rivers in north-central South Dakota. Although the type area was established by Meek and Hayden, subsequent workers have broadened the area of the type area to include areas in Corson, Dewey, and Ziebach Counties (Waage 1961, p. 231). In north-central South Dakota, four members of the Fox Hills have been recognized. The oldest member, the Trail City, is followed by the Timber Lake, the Bullhead, and the Colgate Sandstone. The Trail City, Timber Lake and Bullhead are marine deposits containing an abundance of littoral and sub-littoral fossils.

In the Zeona quadrangle, located about 80 miles west of the type area, the Fox Hills crops out along the North and South Forks of the Moreau River and the Moreau River. The maximum width of outcrop is one-fourth mile and the maximum thickness of exposed strata is about 60 feet. Previous geological maps indicate a greater area of outcrop of Fox Hills (Searight, 1934a; Petsch, 1953) or no outcrop (Darton, 1951) in the Zeona quadrangle. The quadrangle is underlain by the Fox Hills Formation. Although only approximately 60 feet are exposed, it is possible to recognize two distinct lithologic units, but these were not differentiated on the map. Eight stratigraphic measurements were made by the author along the South Fork of the Moreau and the Moreau River. Results of this study indicate that the Fox Hills dips about 8 feet per mile to the northeast which is about the same direction and magnitude as the stream gradient. Because of this, the lithologic units are exposed along the river.

The lowest exposed lithologic unit consists of thin beds of alternating sandstone and shale. Sandstone is gray, fine grained and contains carbonaceous material. Shale is gray and black and occurs as one-half to one-fourth inch layers in the sandstone. The unit varies from less than 5 feet to slightly over 25 feet in thickness. A thin coal bed occurs in this unit, but it pinches out over a 3-mile distance. It is not present in the western portion of the quadrangle, but is present near the eastern border of the quadrangle where the coal reaches its greatest thickness of over two feet. The coal bed is best exposed in a cut bank on the Moreau River in the center of sec. 28, T. 14 N., R. 11 E. A typical exposure of the lower unit is in a cut bank on the South Fork of the Moreau River in the NW¼ sec. 21, T. 13 N., R. 10 E.

The upper unit consists of gray and tan, fine grained, massive sandstone and graywacke. Generally it contains small marcasite and iron-claystone pisolites, spheroidal calcareous concretions of sandstone and graywacke, and carbonaceous material. Thickness varies from less than 5 feet to over 20. Local cross bedding is prominent and in other areas typical foreset beds of siltstone are exposed. A very good exposure of foreset beds is located in NW¼SW¼ sec. 1, T. 13 N., R. 10 E. In all cases the unit is overlain by a 2 to 10-foot thick red carbonaceous shale which marks the base of the Hell Creek. In several areas the calcareous sandstone concretions are very well exposed. A very large concretion crosses the Moreau River channel in the SW¼SW¼ sec. 23, T. 14 N., R. 11 E., forming a three-foot waterfall.

Stratigraphic studies indicate that the red carbonaceous shale is found throughout the mapped area and serves as a useful marker. In several instances the red shale is closely associate with calcareous "salt and pepper" graywacke which forms a resistant, 1 to 2 feet thick ledge. A red stained 4 to 8 inch calcite unit also is associated with these units. The contact between the Hell Creek Formation and the Fox Hills Formation lies within these series of units.

Fossils are rare in the Fox Hills in the mapped area. However, a few pelecypods were collected from a cut bank on the South Fork of the Moreau River in the NE¼NE¼ sec. 24, T. 13 N., R. 9 E. Fossils were not well preserved and crumbled when they were removed from the matrix. They are found near the top of the lower unit described above. Apparently the shells were reworked *Corbicula* sp., but positive identification was impossible due to condition of preservation. About two miles west of this location a cut bank exposure yielded a number of well preserved and diverse molluscs. The bank occurs on the South Fork of the Moreau and is located in the SW¼NW¼ sec. 26, T. 13 N., R. 9 E. The fossils were recovered from calcareous lenses and concretions occurring in the upper portion of the lower unit discussed above. Also recovered from the same concretions were large and small fragments of fossil wood. The fossils in several of the hand samples collected are reworked because the shells appear to be abraded. Small clay-pebbles and several small sharks teeth are also present. The following genera of mollusca were found in this outcrop: *Yoldia* sp., *Lima* sp., and *Inoceramus* sp.

The stratigraphy of the Fox Hills strata found in the Zeona quadrangle suggests that the two lithologic units recognized in the area might be correlated with the Colgate and Bullhead members in areas further to the east. Although Lange (1963) did not recognize the Colgate Sandstone in the Cedar Canyon and Signal Butte quadrangle he did state that the Bullhead Member is present. The lithology of Lange's Bullhead is similar to that discussed above for the lower unit. Lange also reported a 20-foot sandstone and graywacke unit in the upper portion of his Bullhead. This sandstone is similar in lithology to the upper unit discussed above. West of Zeona, French (personal communication, 1965) recognizes the Colgate Sandstone as well as the Bullhead Member. It is entirely possible that the Bullhead correlates with the lower unit and the Colgate is equivalent to the upper unit. Appearance of coal in the lower unit is similar to the appearance of coal in the Stoneville Member of the Fox Hills as described by Searight (1934b, p. 9).

It is apparent from the lithology, depositional structures, and fauna that the Fox Hills strata in the Zeona area are stream and delta deposits that occurred in a sub-littoral environment. Development of good foreset bedding indicates deltaic deposition and the appearance of reworked fossils and associated wood fragments suggests shoreline or brackish water deposition.

*Geologic mapping in the Zeona Quadrangle was completed before Waage, K. M., 1969, was published. Therefore, Waage's terminology used in subsequent quadrangles is not used in the Zeona Quadrangle.

Hell Creek Formation, Brown, 1907, Redefined, Thom and Dobbin, 1924

The Hell Creek Formation is named for exposures of sombre-colored massive sandstones and shales cropping out along Hell Creek, Garfield County, Montana. Type locality of the Hell Creek is approximately 200 miles west of the Zeona quadrangle. The Hell Creek was originally placed in the Upper Cretaceous by Brown (1907) for strata lying above the Fox Hills sandstones and below the Tullock Member of the Lance, but including the Colgate Member of the present Fox Hills, as the basal member of the Lance. Present usage of Hell Creek was defined by Thom and Dobbin (1924).

In the Zeona quadrangle, the Hell Creek is present over the entire quadrangle, except in areas where it has been eroded away. The formation is thickest in the Mud Butte area where it is approximately 350 feet thick and consists of a sequence of brown and red carbonaceous shales, brown and gray "salt and pepper" sandstones and an occasional laterally discontinuous lignite bed. Manganese and iron concretions occur throughout the formation as do marcasite concretions, and claystone concretions. Discontinuous red carbonaceous shales mark the basal Hell Creek and are a useful marker in locating the transitional Hell Creek-Fox Hills contact.

In the southeastern portion of the quadrangle large areas of semi-badlands have developed in Hell Creek sandstone. The sandstone units in this area are argillaceous and because of this the sandstone weathers into vertical flutes. Large manganese-iron concretions are present on the surface in this area as are large spheroidal concretions of sandstone.

Fossil material of plant and animals are rare in this area, although further east the Hell Creek strata contain remains of dinosaurs and petrified wood.

SURFICIAL DEPOSITS

Surficial unconsolidated deposits in the Zeona quadrangle include terrace deposits, alluvium and dune sand. Erosional residuum also occurs scattered on the surface but not in sufficient quantity to warrant mapping.

Alluvium

Alluvium deposits consisting of sand, gravel and clay occur along the major streams and tributaries in the area. Alluvium is found in the present river floodplains, and also as alluvial deposits above the stream channel. The higher level is mapped as older alluvium and represents an earlier floodplain. The higher alluvium deposits are found along the North and South Fork of the Moreau as along the Moreau River. Thickness of the alluvium deposits is variable. Older alluvium is as thick as 30 feet.

The alluvium weathers similarly to that of the Hell Creek formation. Presence of gravel in the deposits aids in identification of the deposit as alluvium.

Terrace Deposits

Three levels of terrace deposits are found along the North and South Fork of the Moreau and the Moreau River. Terrace deposits are also present along Sheep Creek in the northwest area of the quadrangle. Terrace deposits consist of sand and gravel-size fragments of conglomerate, iron-manganese concretions, chert and quartz. All of the deposits are poorly sorted and in many cases exploitation is uneconomical for use as road metal because of the amount of grading that must be done to the material.

Adequate elevation data is lacking in the Zeona area, but three terrace levels can be mapped in the quadrangle. The lowest level is about 50 feet above the stream channel, the second level is about 40 feet above the first level and a third is about 50 feet above the second level. The highest level is found in small areas on top of local hills between major streams.

Residual Boulders

Residual boulders of the Tongue River Formation are present on the surface throughout the mapped area. In the northwest portion of the quadrangle between Sheep Creek and the North Fork of the Moreau, boulders are found in such number that it is impossible to drive through the area. The boulders are tan to buff to gray in color, very hard orthoquartzite, and vary in size from several inches across to more than 3 feet. The boulders often contain branch and leaf impressions.

Sand Dunes

Stabilized and unstabilized sand dune deposits occur along the North Fork of the Moreau River. These eolian deposits are composed of well-sorted gray sand and silt. They are recognized on aerial photographs because of their elongation and the associated blow-outs. In some areas the sand dunes are 12 to 20 feet high and often exhibit cross bedding. The material which makes up the deposits are derived from the floodplain deposits in the area and the Hell Creek sands.

The sand dunes probably range in age from Pleistocene to Recent because they are present on the uplands as well as on the present-day floodplains. Sand dunes which are found over much of western Nebraska and southern South Dakota are known as the Sand Hills Formation (Lugn, 1934) and are assigned to the Pleistocene and Recent.

STRUCTURAL GEOLOGY

Regional structure of the Zeona quadrangle is influenced by the Williston Basin because the area lies on the western flank of the basin. Regional dip is very low. Stratigraphic sections taken along the South Fork and North Fork of the Moreau and the Moreau River are useful in determining the direction and approximate value of the regional dip. A review of the sections shows that a red carbonaceous shale occurs in every section. In the western portion of the quadrangle this shale occurs at approximately 2,675 feet and in the eastern portion the shale occurs at approximately 2,560 feet. The horizontal distance is about 13 miles, thus the regional dip is about 9 feet per mile to the east-northeast. However, the local structure within the quadrangle is limited to several small faults and exposures showing local dip.

Faults were noted in two locations along the South Fork of the Moreau River. A normal fault of approximately 20 feet displacement can be seen in a cut bank on the South Fork of the Moreau in the NE¼SW¼ sec. 1, T. 13 N., R. 10 E. The fault zone is approximately 2 feet wide and is filled with calcareous graywacke which shows structures indicating it might have moved plastically in the fault plane. The attitude of the fault plane is N. 75° E. 60° S. Another normal fault was noted about two miles west along the South Fork of the Moreau in SW¼SE¼ sec. 3, T. 13 N., R. 10 E. Displacement on this fault is approximately 30 feet and the apparent attitude of the fault plane is about N. 45° E. 70° S. However, the fault plane is not well exposed and accurate measurements could not be obtained.

Minor flexures are present along the major streams, but generally do not exceed five feet in magnitude. Gently dipping strata were noted in NW¼NE¼ sec. 3, T. 13 N., R. 10 E., where Fox Hills and Hell Creek strata dip to the east at about 20 degrees. The dip does not persist to the east as the strata within a mile are almost horizontal. Another outcrop of dipping strata occurs in the SE¼NE¼ sec. 22, T. 14 N., R. 11 E., where Hell Creek strata dip 20 degrees to the east.

Previous geologic maps of the area suggest that the Zeona quadrangle lies on the nose of an eastward plunging anticline (Searight, 1934a, b; Petsch, 1953). Evidence of such a structure was not found in the Zeona quadrangle by the author.

ECONOMIC GEOLOGY

Ground water, sand, gravel, and boulders comprise the chief mineral resources of the Zeona quadrangle. Clay, manganese, iron, uranium, and bentonite are present in very limited quantities and at present time are not economically important deposits.

Ground Water

Ground water is available in all areas of the Zeona quadrangle. The quantity and quality of the water appears to be adequate for domestic and agricultural use. Flowing wells are not present in the quadrangle, but one exists approximately 10 miles west of Zeona along the North Fork of the Moreau River.

Gravel

Gravel deposits are found on the terraces along the North and South Forks of the Moreau River, the Moreau River, and Sheep Creek. The quality of gravel is poor due to the high iron and manganese content which makes the deposits unsuited for use as road metal and concrete aggregate.

Gravel has been quarried from a pit located on the South Fork of the Moreau in the NW¼ sec. 16, T. 13 N., R. 10 E.

Sand

An abundant amount of sand exists in the Zeona quadrangle. The sand is in the form of massive cross-bedded fine- to medium-grained sandstone and graywacke in the Hell Creek and Fox Hills Formation and in the sand dunes located along the North Fork of the Moreau River. Easily obtained sand is present in the upper Fox Hills and it contains only small amounts of clay. The sand found in the Hell Creek has a higher clay content and is less friable.

Other Potential Mineral Resources

Iron-manganese concretions and **iron claystone** are present in the Hell Creek; however, the volume in any one area does not warrant commercial exploitation of these rocks. **Gypsum** and **selenite** is encountered sporadically in the Hell Creek, but never in great abundance. **Lignite** has been utilized by local ranchers for fuel, but no active mines exist in the mapped area. Coal also occurs in the Fox Hills, especially along the Moreau River in sec. 21, 22, 28, 30, 31, 32, and 33, T. 14 N., R. 11 E. The coal is found either in a single 1 to 2 foot thick bed or as several thinner beds separated by thin sandstone beds. Although in other portions of northwestern South Dakota **uranium** has been found in lignite and coal deposits, none has been reported in the lignites and coal of the Zeona quadrangle. **Ceramic clay** has not been reported in the Zeona quadrangle, but it is possible that good ceramic clay might occur locally in the Hell Creek. **Bentonite** in the Hell Creek Formation is very impure and not of economic importance.

Oil and Gas Possibilities

The Zeona quadrangle lies on the southwest flank on the Williston Basin which has been known for the past twenty years for oil production in North Dakota and Saskatchewan, Canada. The nearest oil field is the Buffalo South Dakota Field, approximately 40 miles northeast of the Zeona area. One oil test has been drilled in the Zeona quadrangle to date, the Mule Creek No. 41-33 State (Mud Butte A) located in the center of NE¼NE¼ sec. 33, T. 13 N., R. 10 E. This test was drilled to a depth of 6,908 feet, but did not reach basement rock. Although there were several oil shows, none were sufficient to establish production. Table 1 summarizes the thickness and lithology of the formations underlying the Zeona quadrangle.

Table 1.–Summary of formations encountered in Mule Creek 41-33 State, Zeona quadrangle, South Dakota

System	Group	Formation	Interval	Thickness	Lithology
		Hell Creek			
		Fox Hills			
		Pierre	570-2120	1550	Shale, medium-dark gray, blocky, with thin bentonites.
		Niobrara	2120-2310	190	Chalk, light-medium gray, white speckled microfossiliferous.
		Carlile	2310-2645	335	Shale, medium-gray, plastic, non-calcareous
		Greenhorn	2645-2715	70	Limestone, impure, slabby, macrofossiliferous
		Belle Fourche	2715-3160	445	Shale, dark-gray, blocky, many thin bentonite seams.
		Mowry	3160-3270	90	Shale, light-medium gray, siliceous
		Dakota	3270-3330	60	Sandstone, very fine grained quartz, tight
		Skull Creek	3330-3550	220	Shale, medium-dark gray, glauconitic siltstone near middle of unit
	Inyan Kara	Fall River	3550-3660	110	Sandstone, fine-medium grained quartz, friable, porous
		Fuson	3660-3700	40	Shale, varicolored, plastic-pellet bearing
		Lakota	3700-3890	190	Sandstone, fine-medium quartz, friable and porous
Jurassic		Morrison	3890-4030	150	Shale, gray to greenish-gray
		Sundance	4030-4150	120	Sandstone, fine-grained, glauconitic.
Triassic		Spearfish	4150-4570	420	Siltstone, brick red, clayey–gypsum beds common
Permian		Minnekahta	4570-4700	120	Limestone, light pink-maroon, fine, dense
		Opeche	4700-4745	45	Shale, claystone, brick red, silty
	Minnelusa	Cassa	4745-4780	35	Siltstone, clayey, brick red, non-porous
		Broom Creek	4780-4910	130	Anhydrite, red shales and limestones, light colored
Pennsylvanian		Wendover-Meek	4910-5020	110	Limestone, anhydrite, light colors, red shale marker at top
		Hayden	5020-5145	125	Limestone and shale, black, radioactive
		Roundtop	5145-5255	110	Shale, varicolored, floating quartz grains
		Reclamation	5255-5310	55	Limestone, white-block, fine, dense
		Fairbank	5310-5400	90	Sandstone, fine-medium clayey, tight
Mississippian	Madison	Charles	5400-5670	270	Anhydrite and limestone, light colored
		Mission Canyon	5670-5830	160	Limestone, white-light tan, oalitic-lithographic
		Lodgepole	5830-6300	470	Dolomite, light brown, fine-medium, dense-sucrosic
		Englewood	6300-6350	50	Limestone, pale maroon, orgilloreous
Devonian		Duperow	6350-6540	190	Dolomite and limestone, light brown, fine, dense
Silurian		Interlake	6540-6670	130	Dolomite, light tan to brown, sandy at base
Ordovician	Big Horn	Stoney Mountain	6670-6750	80	Dolomite, light gray, siltstone, white, shale, light green at base
		Red River	6750-7320*	570	Dolomite, light-medium brown, fine-medium grained, sucrosic to dense
		Winnipeg	7320*-7400*	80	Sandstone, white, friable, shale, green with phosphate pellets
Cambrian		Deadwood	7400*-7900*	500	Dolomite, light gray, glauconitic, sandy and shaley
Precambrian		Granite	7900*		

*Total depth of test 6,908 feet. Depth sand thickness estimated from 6908-7900.

REFERENCES CITED

Brown, Barnum, 1907, The Hell Creek beds of the Upper Cretaceous of Montana: Amer. Mus. Nat. Hist. Bull., v. 23, p. 823-845.

Darton, N. H., 1951, Geological map of South Dakota: U. S. Geol. Survey.

Lange, A. U., 1963, The geology of the Cedar Canyon quadrangle: S. Dak. Geol. Survey, map and text.

Lugn, A. L., 1934, Outline of the Pleistocene geology of Nebraska: *in* Barbour, E. H., The geology and Mammalian fauna of the Pleistocene of Nebraska: Nebr. State Museum Bull. 41, v. 1, p. 319-355.

Meek, F. B., and Hayden, F. V., 1861, Descriptions of New Lower Silurian (Primordial), Jurrassic, Cretaceous, and Tertiary fossils, collected in Nebraska territory, with some remarks on the rocks from which they were collected: Acad. Nat. Sci., Philadelphia Proc. p. 415-447 (1862).

Petsch, B. C., 1953, Geologic map of South Dakota: S. Dak. Geol. Survey.

Searight, W. V., 1934a, Geology of central Perkins County: S. Dak. Geol. Survey, Rept. Inv. 21, p. 52.

, 1934b, The Stoneville coal area: S. Dak. Geol. Survey, Rept. Inv. 22, p. 1-24.

Thom, W. T., and Dobbin, C. E., 1924, Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. Amer. Bull., v. 35, p. 381-506.

Waage, K., 1961, The Fox Hills Formation in its type area, central South Dakota: Wyo. Geol. Assoc. Guidebook, Symposium of Late Cretaceous Rocks of Wyoming, 16th Ann. Field Conf., p. 229-240.

, 1969, The type Fox Hills Formation Cretaceous (*Maestrichtian*) South Dakota, Part I: Stratigraphy and Paleoenvironment: Peabody Mus. Nat. History Bull. 27, Yale University, New Haven, Conn.

U. S. Department of Interior-Geological Survey, 1963, Surface water records of North Dakota and South Dakota, p. 255.