SOUTH DAKOTA

STATE GEOLOGICAL SURVEY

E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS

No. 31

A STRUCTURAL SURVEY OF PART OF THE UPPER MISSOURI VALLEY IN SOUTH DAKOTA

By

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Vermillion, S. Dak.

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ARTESIAN WELL DATA

Owner	Locality	Driller-Date	Datum--Sea Level					Gas
			Depth	El. Top Well	El. Top Water Sand	Length Screen	El. Bottom Well	
Wm. Wilson (gas used in house)	SE¼Sec.25,T122N,R78W,Walworth	1926	1752	1812	62	64	+60	Yes
Schlaller	NE¼Sec.11,T117N,R79W,Potter							Yes
M & St.L.R.R. Co.	LeBeau Walworth County	1907	1498	1547		?	+49	Yes
M & St.L.R.R. Co.	NE¼Sec.3,T121N,R77W,Akaska		1686	1699	+93	80	+13	Yes
M & St.L.R.R. Co.	NE¼Sec11,T121N,R76W,Lowry		1800	1873	103	30	+73	
Eiteneier	SE¼Sec19,T121N,R78W,Walworth	1925	1785	1825			+40	
Fox-drilled as oil test	SE¼Sec18,T118N,R76W,Potter	1910-11	2260	2071	311	None	-189	?
Gettysburg #1 Well	NW¼Sec25,T118N,R76W,Potter	Norbeck-1901	2130	2089	+309		-41	No
Gettysburg #2 Well	NW¼Sec25,T118N,R76W,Potter	Norbeck-1924	1917	2090	301		+173	No
Cheyenne Agency	SE¼Sec2,T12N,R31E,Dewey	1900±	1337	1537	+225		200	Yes
Carl Cosand, now by Rural Credit Corp.	SW¼Sec19,T118N,R77W,Potter	Norbeck&Nichols	1722	1902			+180	No
Rabe	SWSec27,T113N,R79W, Sully	1934-35		1840				Yes
Clarence Nelson	NW¼Sec29,T118N,R77W, Potter	Norbeck-1926	1950±	1916	-34			No
Ray Rosa	SE¼Sec8,T118N,R77W, Potter	Norbeck-Nicholson Hans Berg-Driller 1918	1797 deepened-1825	1987	Above 190	None	+162	None
Nels Peterson	SW¼Sec7,T120N,R76W, Potter	Norbeck-1925	1950±	2101			+251	Littl
Soutner	NE¼Sec6,T120N,R76W, Potter	Norbeck-1917	1855±	2059	204			Yes

LIST OF ILLUSTRATIONS

WELL RECORDS

A STRUCTURAL SURVEY OF PART OF THE UPPER MISSOURI VALLEY IN SOUTH DAKOTA

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I. INTRODUCTION

Location: The area covered by this report is located in the north central part of South Dakota, and comprises parts of Dewey, Potter and Walworth Counties. (Figure 1) The report includes a detailed structural study of the Missouri River breaks, extending from a few miles south of Cheyenne Agency, north to the mouth of the Moreau River, a north-south distance of approximately twenty-six miles. As it includes a study of formations exposed in the breaks, the width of the strip covered is variable, and ranges from one to five miles on either side of the Missouri.

Inclusion in the report of structural information yielded by records of nearby artesian wells extends the area covered to as much as twenty miles east of the river.

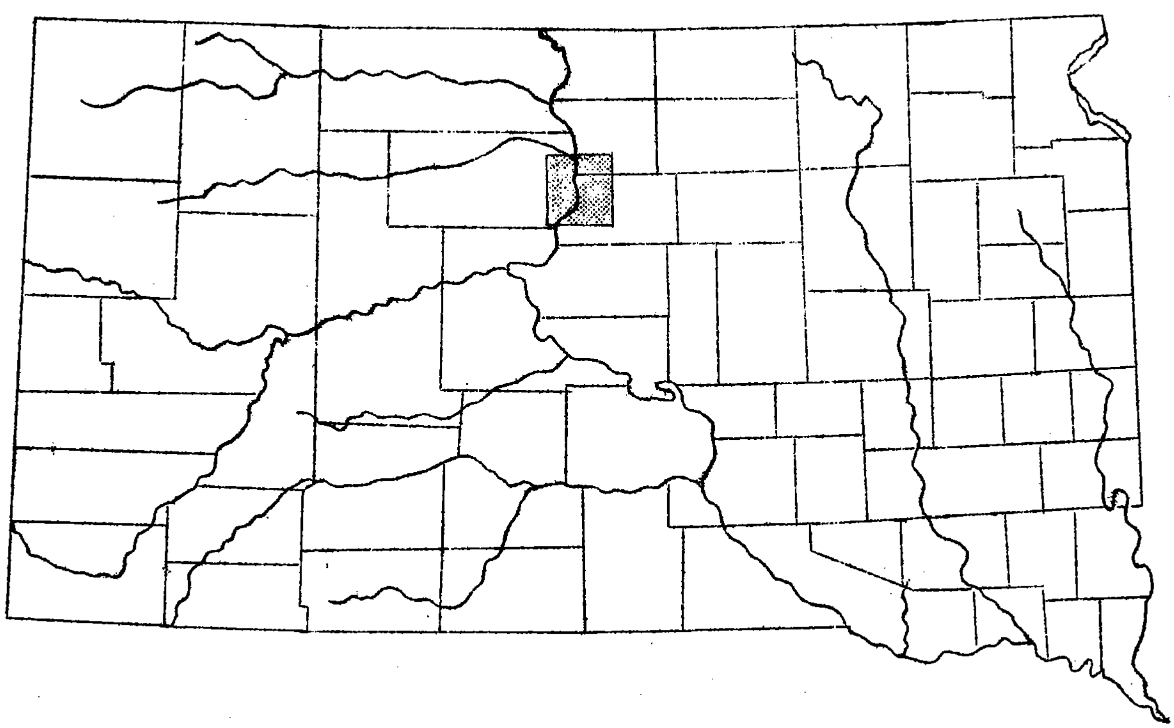

Figure 1. County outline map of South Dakota, showing the area covered by this report stippled.

II. PURPOSE

The purpose of this investigation has been to determine the detailed structure of the surface rocks with special reference to oil and gas accumulation. Inasmuch as the area has never been prospected for gas or oil, its possibilities are entirely unknown. This report, therefore, is intended to serve as a guide for anyone desiring to test the area in the most efficient manner. The most suitable structures are indicated, and some of the problems connected with test drilling are outlined.

Particular interest in the gas possibilities has been brought about by the presence of small quantities of gas encountered in many of the artesian wells drilled in the area during the last forty years. In some cases the flow of gas has been sufficient to supply the well owner with lighting, heating and cooking gas over a period of many years. The fact that the gas-producing wells are more or less closely grouped has suggested that the accumulation of gas may be due at least in part to the structure of the underlying rocks. In this report an effort has been made to show the location of the gas-giving wells relative to the structure as determined by the study of surface outcrops.

Discovery of even small quantities of gas would be of considerable benefit to ranchers, farmers, and to nearby towns, whereas the development of larger resources, either of oil or gas or both, would be of the greatest advantage to the entire state.

A preliminary geologic report on the oil and gas possibilities of part of this area was published by the State Geological Survey in 1930.[1] The presence of numerous small structures in the Pierre shale was pointed out at that time, and the foundation laid for a more extensive and more detailed survey of the region. Although different phases of the Pierre shale in the Missouri valley region had long been noted, it was not until the first survey was made in this area that certain of these features were recognized to be sufficiently constant over wide areas to serve as key horizons upon which structural mapping might be done. Subsequent field and laboratory work by Dr. W. V. Searight has resulted in the subdivision of the Pierre formation of the Missouri Valley of South Dakota into five main subdivisions, some of which are themselves divisible into definite zones.[2]

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1. William L. Russell, The Possibilities of Oil and Gas in Western Potter County, Report of Investigations, No. 7, S. Dak. Geol. and Nat. Hist. Survey, Dec., 1930.
2. W. V. Searight, Lithologic Stratigraphy of the Pierre Formation of the Missouri Valley in South Dakota, Report of Investigations No. 27, S. Dak. State Geological Survey, January, 1937.

Note: Subsequent reference to these two papers will be made by author's name and page number in the text.

The first practical use of these subdivisions was made by this Survey during the summer of 1937, at which time the structure of the Pierre Gas Field was determined on one of these key horizons.[1] The validity of the subdivisions of the Pierre was shown so clearly in that study that their further use during this investigation is highly justified. The present study has shown the soundness of the stratigraphic subdivisions in this area, and has also made it possible to contribute detailed information concerning the local characteristics of some of these members and zones of the Pierre shale. The large number of detailed geologic sections included in this report will serve not only as an aid for future work in the area mapped, but also as a standard of comparison in other areas.

1. Monta E. Wing, A Structural Survey of the Pierre Gas Field, South Dakota, Report of Investigations No. 29, S. Dak. State Geological Survey, March, 1938.

III. NATURE AND SCOPE OF WORK

Field work for the present report was done during the months of July and August, 1938. Camp was established at Whitlock's Crossing, Potter County, at the east end of the Forest City Bridge, so that both sides of the Missouri River would be equally accessible.

The survey has been of the type frequently used in determining geologic structures in areas where outcrops are numerous. The elevation of the outcrop of some readily recognized key bed is determined at frequent intervals by means of a plane table and telescopic alidade, and the structure of the surface rocks determined by contouring points of equal elevation. In areas whose general structure and geologic history are known, the structure of deeper rocks may be predicted with considerable accuracy from such a surface study.

Two plane table parties were used, each consisting of an instrument man, recorder, rodman, and geologist who served as a second rodman. Instrument men were Mr. H. E. Brookman and Mr. Dan Ihle; geologists were Dr. E. P. Rothrock and the writer. Assistants for the summer included Messrs. Carl Wince, Clarion Kjeldseth, and Raymond Maloney. Elevations were determined by plane table surveys, controlled at frequent intervals either by Missouri River Commission or U. S. Coast and Geodetic Survey benchmarks in the area, or by precise levels brought into the area from nearby benchmarks by means of the Dumpy level.

The key horizon upon which mapping has been done is the contact of the Agency shale and the overlying Oacoma zone. This is by far the most striking lithologic break exposed in the area, but as it occurs in the lower part of the local geologic section, outcrops are found close to the river in most places, and even in the deepest tributary valleys they cannot be traced for more than four or five miles from the Missouri.

In a few places, elevations of higher key zones have been determined, and the elevation of the top of the Agency estimated from those figures after careful study of the complete local geologic section. This has been particularly necessary at the northern edge of the area mapped, where the Agency shale dips below the level of the Missouri river.

Mapping was complicated in parts of the area east of the river by the presence of glacial drift which largely obscured the underlying shale. Gravel terraces on both sides of the river also covered small areas, but to a lesser extent than the drift.

In addition to the outcrop study, the elevations of many artesian wells east of the river have been determined, and an effort made to compare the structure on top of the first water sand with that determined from the outcrops.

Possibilities for more extensive or detailed work in the region will be discussed at greater length later in the paper. Briefly, they include trenching to determine the exact contact of the Agency and Oacoma zones for mapping with greater accuracy over the present area, and the extension of the present survey in all directions by use of higher, less easily determined zones.

IV. STRATIGRAPHY--SUBSURFACE FORMATIONS

For knowledge of the formations lying below the Pierre shale in this area, we must rely upon deep well records. Our knowledge of the Cretaceous rocks down to and including the Dakota sandstone is furnished by many artesian wells, but below that horizon the data is meager. We must turn to the Black Hills, where older rocks crop out, and to the few exceptionally deep wells lying between this area and the Hills and in North Dakota. By a comparison of the records of these wells, it is possible to trace the formations eastward under the plains. Thus the gradual changes in thickness and lithologic character of the various formations can be observed, and a close estimate made of conditions existing beneath this area. Plate I shows the probable character and thickness of the formations to be encountered in deep drilling in this region.

A brief discussion of the characteristics of these rocks follows, beginning with the lowest and oldest, and progressing toward the surface. Detailed logs of several significant wells are included at the end of this chapter. Even more complete descriptions of these formations may be found in the sample studies of the Zeal and Ole Tanberg wells drilled by the Cosden Oil Company.[1]

Beneath the Paleozoic sedimentary rocks lie an unknown thickness of igneous and metamorphic rocks of pre-Cambrian age. In the Black Hills they consist mainly of schist, quartzite and granite, but in the eastern part of the state, the thick Sioux Quartzite is the most conspicuous member. As oil does not occur in pre-Cambrian beds, prospecting should not be extended into these formations.

PALEOZOIC ROCKS

The oldest Paleozoic beds in the Black Hills consist of a series of alternating sandstones and shales deposited during upper Cambrian time. Overlying these in the northern Hills are a shale and thick limestone of Ordovician age. No Silurian or Devonian rocks are found in the Black Hills section, but they are known to be present in eastern Montana and North Dakota (See Appendix vii), so there is a bare possibility that they are present in this area. It seems doubtful, however, that they would be found so far south in this region, and, if present, they are undoubtedly very thin. Mississippian limestones reach a maximum thickness of 700 feet in the Hills, and are known to be widespread in and east of the Rocky Mountains. The Standing Butte well in Stanley County (See Appendix iii) was finished in the Pahasapa after penetrating nearly 500 feet of the formation. A thick Pennsylvanian sandstone with interbedded shales and limestones, known as the Minnelusa formation overlies the "big lime." This formation becomes much more shaly eastward from the Hills, as indicated by the record of the Standing

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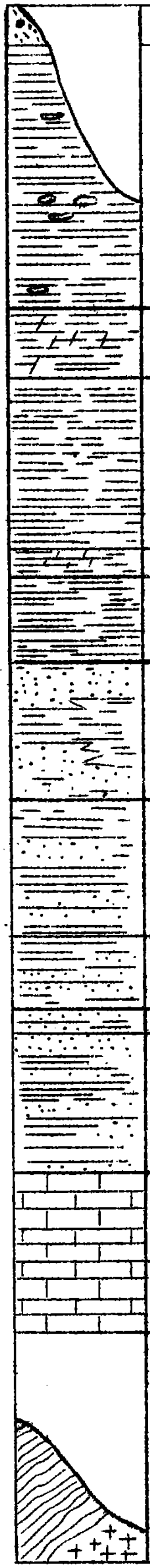
1. E. R. Applin, A Micro-Fossiliferous Upper Cretaceous Section from South Dakota, Journal of Paleontology, vol. 7, no. 2, June, 1933, pp.215-220.

PLATE I

Generalized Columnar Section



0 - 100	Surficial materials.	Soil, till, gravel silt, loess, etc.
300 - 750	Pierre formation.	Gray to brown shale, with concretions and bentonite beds.
200	Niobrara formation.	Chalk and calcareous gray shale.
500	Carlile shale.	Dark gray to black shale.
60	Greenhorn formation.	Limestone and shale.
275	Graneros shale.	Dark gray shale
250 - 500	Dakota formation.	Sand, some shale.
	Fuson shale.	Varicolored shale.
	Lakota formation.	Sandstone, some shale
450	Morrison formation	Sand, clay, and shale
	Unkpapa sandstone	
	Sundance formation	
150	Spearfish formation.	Redbeds.
50	Minnekahta & Opeche.	Sandstone & redbeds
400	Minnelusa formation.	Sandstone, shale, limestone, gypsum and redbeds.
500	Pahasapa limestone.	
	Probable Cambrian, and possible Ordovician Silurian, and Devonian formations.	
	Pre-Cambrian metamorphic and igneous rocks	

Butte well. The Permian period is represented in the Black Hills area by the purplish-red Opeche shale and by the thin red and white Minnekahta limestone, with a combined thickness of about 160 feet. Eastward these become much more shaly and sandy, and thin considerably. In this area, there seems to be a more complete transition from Permian into Triassic beds than is indicated by the Black Hills section.

MESOZOIC ROCKS

The Spearfish redbeds and gypsum, which reach a thickness of nearly 700 feet in the Black Hills area, thin to about 150 feet in Stanley county. Between the redbeds and the base of the Lakota-Fuson-Dakota sandstone group, lie varicolored clays and sands belonging to the Sundance, Unkpapa and Morrison formations of Jurassic age. This series reaches a thickness of nearly 500 feet in the Ole Tanberg well in southwest Ziebach County (Appendix vi), and well over 400 feet in the Standing Butte Well. The sandstones and shales of the Dakota group, at their outcrop around the Black Hills consist of two distinct sandstone members separated by a thin shale. But a study of hundreds of artesian well records throughout the state indicates that this series becomes more a group of lenticular sandstones interbedded with shale and sandy shale.[1] The first sandstone sufficiently clean to yield an artesian flow, therefore, does not always occur at the same horizon in the Dakota group. This in part accounts for the variation in elevation of the first water sand over limited areas. The records of some of the artesian wells in the eastern part of this area are shown in an accompanying tabulation (Appendix viii). The variable nature of this series may also be seen from the detailed logs of the Cheyenne Agency, Gettysburg no. 2, and Whitehorse wells.

The formations between the Dakota and the base of the Pierre are, in ascending order, the Graneros shale, the Greenhorn limestone and calcareous shale, the Carlile shale, and the Niobrara calcareous shale or chalk. This thick series of gray shales is difficult to subdivide in well drilling except by microscopic study of sample drill cuttings. Minor changes in lithology and fossil content can be observed in this way which cannot be determined by the driller. For this reason the thickness of any particular formation as determined by the driller may vary considerably from that determined after careful sample study.

The thickness of the Graneros shale as shown by drillers' logs in this area is uniformly close to 275 feet. This interval between the lowest limestone of the Greenhorn and the first

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1. For discussion of the nature of the Dakota sandstone, see E. P. Rothrock, <u>Artesian Conditions in West Central South Dakota</u>. Geology. Report of Investigations No. 26, S. Dak. State Geological Survey, 1936, p. 27.

sandy shale in the Dakota is recorded as a blue or black shale. Under the microscope the shale appears dark gray, becoming brown or nearly black near the top.

The Greenhorn and Carlile formations cannot be accurately separated except from sample studies. The difficulty lies in the fact that the Greenhorn contains only scattered limestone lenses which can be recognized by the driller. The upper part which is dominantly calcareous shale is grouped with the overlying Carlile. The latter is consistently logged as black shale. In drillers' logs of wells in this area the combined thickness of these two formations varies from 475 to 560 feet. The variations seem more likely due to difficulty in picking the exact upper contact than in actual differences in thickness of the formations.

Between the Carlile and the Pierre lies the very calcareous Niobrara formation. Although it appears as a chalk in outcrops, it shows only as a gray to black shale in wells. Searight (page 4) considers the relation between the Pierre and the Niobrara to be one of conformity. The similarity of the Niobrara to the lowest beds of the Pierre makes it practically impossible for the driller to locate the division point. Under the microscope the contact is easily located because of the characteristic "speckled" appearance of the Niobrara. However, there are not enough sample studies available to show the variations in thickness of the formation. About 200 feet are usually exposed in outcrops. In drilling, 50 feet or so of "gray sandy shale" are usually reported; the remainder is usually recorded as "Pierre" shale.

V. STRATIGRAPHY--THE EXPOSED FORMATIONS

The formations appearing at the surface in this area may be divided into two very distinct groups, the various subdivisions of the Pierre shale which form the bedrock, and the surficial mantle of glacial till, silt, loess and gravel which overlies the shale in much of the region.

PIERRE FORMATION

This formation may be defined as a thick gray shale lying with apparent conformity upon the Niobrara chalk and beneath the Fox Hills sandstone. It underlies a large portion of the state. West of the Missouri, it is present at or below the surface everywhere except over and around the Black Hills and a few small areas in the lower Missouri valley. East of the River, the distribution is not so well known, due to the mantle of glacial drift which covers it. Well records and outcrops in which it has been identified indicate that it is present under most of that part of the state.

Although not far to the west the Pierre is overlain by younger Cretaceous and Tertiary beds, it everywhere forms the bedrock of the area under consideration. The total known thickness of the uneroded Pierre in South Dakota has been shown by Searight (page 56) to vary between about 400 and 1100 feet. However, in this area, the present topography has been carved in the Pierre shale, so that the remaining thickness at any point depends not only upon the structure but upon the elevation. The thickness of the formation, therefore, ranges from probably less than 300 feet in the valley at Cheyenne Agency to as much as 750 feet on the upland in the northern part of the area.

W. L. Russell made the first effort to subdivide the Pierre of this area into members or zones. The different lithologic phases were described, but only one member was named, and no detailed sections were given. Searight studied the entire Pierre shale section in the Missouri Valley of South Dakota, and extended his observations to other parts of the state and to adjacent areas. As a result of these studies, he has subdivided the Pierre formation into five members, several of which may in turn be further subdivided into zones. Plate II shows the generalized columnar section of the Pierre as worked out by Searight. Although all of the members are not exposed in this immediate area, each will be discussed here in some detail. Detailed sections of several subdivisions of the Sully and Virgin Creek members are included to show their local development.

GENERALIZED COLUMNAR SECTION OF THE PIERRE FORMATION

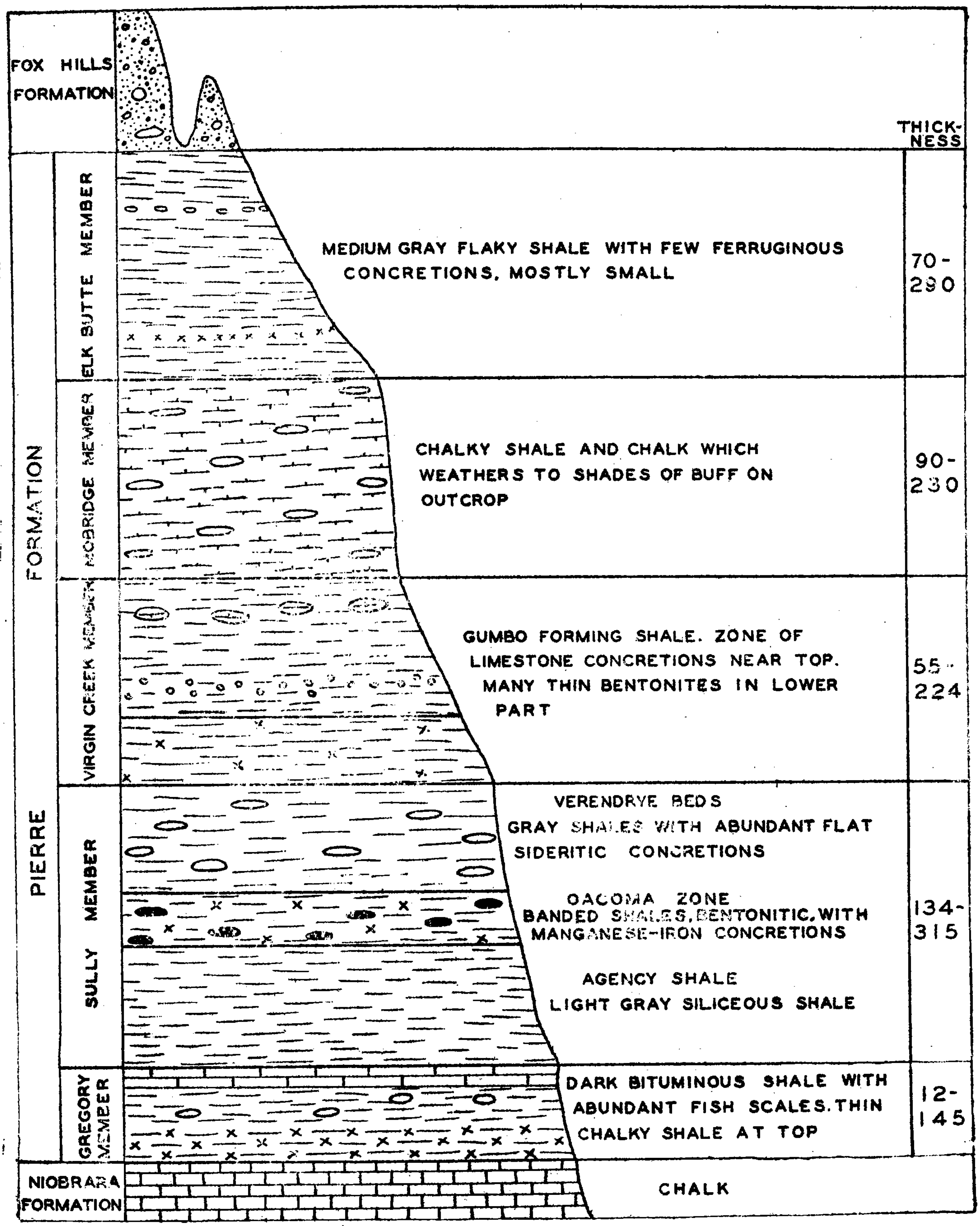


PLATE II

R.T.

Gregory Member

This member was named by Searight (page 10) from exposures along the Missouri River in Gregory County, South Dakota. It crops out along the river as far north as Hughes County, where it disappears beneath younger beds. It is consequently not exposed in Potter, Dewey or Walworth counties, but undoubtedly underlies the whole area.

The lower part of the Gregory consists of thin-bedded, flaky, dark, nearly black bituminous shale, interbedded with thin layers of bentonite. Concretions may be present. Forty-three feet are noted at the type locality.

In outcrops, the upper Gregory consists of a thin succession of chalky shale or marl, but it is doubtful if the chalk would be noticed in drilling through the formation. In the south central part of the state the two divisions are separated by up to two feet of fine grained sandstone at the base of the upper Gregory which might be observed in drill cuttings. The thickness of the upper Gregory zone is eleven feet at the type locality.

The total thickness of the Gregory member is extremely variable over the area of outcrop, varying from 12 feet near Yankton to over 145 feet near Reliance. Along Crow Creek, 13 miles north of Chamberlain, the member again thins to 60 feet. Since this member cannot be identified from drillers' logs, there is little evidence as to its thickness in the area under consideration (See page 29). A tentative estimate would place the thickness between 50 and 200 feet.

Sully Member

This member was named by Searight (page 21) for characteristic exposures along the Missouri in and opposite Sully county, South Dakota, although the type localities for the different subdivisions of the member range from Lyman county on the south to Dewey county on the north. The total known thickness of the member according to Searight (page 34) varies between 134 and 315 feet. At least 275 feet are known to be present in the area under consideration.

The Sully has been defined as including the group of shales lying between the chalky beds of the upper Gregory and the base of the highly bentonitic beds which form the lower Virgin Creek Member. This member is exposed along the Missouri River in South Dakota from the Nebraska state line northward to Mobridge, Walworth county, and has been observed as far east as Yankton and as far west as Meade county.

The Sully member has been subdivided into three subdivisions (Searight, page 22) which seem valid where ever the beds are found in South Dakota, and further work may extend their use outside of the state. These are in ascending order the Agency Shale, the Oacoma zone, and the Verendrye shale zone. Inasmuch as all three of these zones are well exposed in Potter and Dewey counties, they will be considered separately and in considerable detail.

Agency Shale zone: The Agency Shale was named by Russell (Page 5) from typical exposures along the Missouri River at the Cheyenne River Indian Agency. The zone first appears along the Missouri River a short distance south of the Moreau, and continues south along the river and for short distances up the larger tributaries as far south as Crow Creek, Buffalo County, where the zone thins out and disappears.

The Agency thus forms a great wedge of siliceous shale, gradually thickening to the north. The measured thickness of the zone exposed above the river's edge at the type locality is about 120 feet, but taking the dip of the beds into consideration the actual thickness is probably about 115 feet above the level of the river. Measurements taken on top of a structure a few miles north of the type locality suggest that the total thickness must be greater than 150 feet.

The Agency zone is composed of light gray siliceous shale which weathers to brittle plates or chips. It does not weather to gumbo, but stands up as strong silvery outcrops. In fresh exposures the shale breaks out into rectangular joint blocks several inches to a foot or more square and several inches thick. The joints are frequently stained dark brown or purple. Further weathering breaks up the blocks into small angular flakes which clink like slate and are harsh to the touch. One set of vertical joints is usually more conspicuous than the other, and although their direction remains nearly constant over one outcrop, they seem to be directly related to the small local structures rather than to any regional structure.

Light gray concretions up to two feet or more in diameter which weather rusty on the surface are conspicuous in the upper part of the formation in this area. A lower zone observed in the type section is not conspicuous in other exposures.

Inasmuch as the contact of the Agency with the underlying Gregory is not exposed in the area, the stratigraphic relation between the two has not been determined. The contact with the Oacoma appears to be one of gradation from siliceous shale below, through alternating siliceous shale and bentonite, to alternating non-siliceous shale and bentonite. Although the vertical distance from the uppermost concretions in the Agency to the lowest bentonite in the Oacoma zone is variable, it is not believed that the uppermost concretions observed in any one outcrop necessarily indicate the top of the formation.

There is no field evidence of a break in sedimentation between the two zones. It thus appears that the top of this zone forms a valid horizon upon which structural features may be determined.

A few very thin beds of bentonite and bentonitic shale are noted in the lower part of the type section of the Agency. A 4 to 5 foot zone including several bentonite beds is seen about 70 feet below the top of the formation in the type section. (See Table I).

A peculiar occurrence of bentonite beds and a lense of volcanic ash has been observed about 25 feet below the top of the Agency near the mouth of Steamboat Creek, Sec. 28, T. 20 N., R. 78 W., Potter County. (Table II). A three and one-half foot shale zone including five bentonite beds two inches or less in thickness occurs about 21 feet below the top of the Agency. Several layers of large Inocermaus shells are also included. In an adjacent outcrop, at a distance estimated at eight feet below the lowest bentonite, is the top of a lentil-shaped deposit of volcanic ash about 12 feet thick and 25 feet across. Under the microscope, the material appears to be a pure, finely divided volcanic glass. Considerable slumping at the outcrop makes it difficult to determine the true distance from the top of the ash lens to the top of the Agency. Some thin shale beds seem to be pinched out or removed beneath the lens, but lack of time has prevented the exact determination of the relations of the ash lens to the shale.

The top of the Agency typically forms a bench in the outcrop, and in parts of the area, valley floors and large terraces seem to be developed at this horizon. The formation is less subject to slumping than the overlying members.

<u>Oacoma shale zone</u>: The Oacoma zone was named by Searight (page 23) from exposures at Oacoma, Lyman County, and northward along the Missouri River to the Great Bend.

The zone has been described (Searight, page 24) as follows:

> "The Oacoma zone consists of beds of gray shale varying from a few inches to a few feet in thickness, alternating with very thin beds of bentonite and bentonitic clay. Near Oacoma and northward to the great Bend and southward into Charles Mix county, it may be that bentonite is more or less disseminated through the shale as well as being concentrated into thin beds of relatively pure bentonite because the outcrops in this area weather down to bentonitic gumbo.
> .....North of the Great Bend the Oacoma zone is composed of beds of light gray, flaky shale with thin dark clays interbedded as elsewhere. Here, however, the flaky,

TABLE I

Succession of beds, Agency shale zone, opposite Whitlock's Crossing, in eastern Dewey County, South Dakota.

Detailed section made by plane table in first ravine north of Forest City Bridge, and in highway cut immediately south of bridge. SW$\frac{1}{4}$ Sec. 35, T 13 N, R 31 E and N$\frac{1}{2}$ Sec. 1, T 12 N, R31E.

	Feet	Inches
Oacoma zone		
16. Shale, light gray, siliceous		
15. Bentonite----------------------------------		1
Agency shale zone		
14. Shale, light gray, siliceous. Weathers to light gray flakes which are harsh to touch and clink together like slate. No concretions in highway cut, but they are abundant in nearby outcrops---------------	13	
13. Shale, as above, containing light gray concretions up to 2 feet across and 8 inches thick which weather into rusty colored fragments. Concretions most abundant near top of this zone in highway cut----------------------------------	12	
12. Shale, as above, containing no concretions	42	11
11. Bentonite----------------------------------		1
10. Shale, as above----------------------------	2	2
9. Bentonite-----------------------------------		$\frac{3}{4}$
8. Shale, as above-----------------------------		3
7. Bentonite-----------------------------------		$\frac{3}{4}$
6. Shale, as above-----------------------------	1	8
5. Bentonite-----------------------------------		$\frac{1}{2}$
4. Shale, as above-----------------------------	8	3
3. Shale, as above, including large gray concretions up to 2 feet in diameter and 1 foot thick---------------------------------	4	
2. Shale, dark gray, bentonitic--------------		4
1. Shale, light gray, siliceous, may include a few very thin bentonite beds near base----------------------------------	30	4
River level		
Total thickness Agency ------	115	

TABLE II

<u>Succession of beds, Steamboat Creek, western Potter County, South Dakota.</u>

Detailed section of Agency shale near mouth of creek, NW$\frac{1}{4}$ Sec. 28, T. 20 N., R. 78 W., thickness estimated.

	Feet	Inches
<u>Oacoma zone</u>		
6. Shale, including at least 10 thin bentonite beds------------------------	5	
<u>Agency shale zone</u>		
5. Shale, light gray, siliceous, no concretions visible---------------------	21	
4. Shale, light gray, siliceous, including 5 bentonite beds varying in thickness from $\frac{1}{2}$ inch to 2 inches---------	3	6
3. Shale, same, with large rusty concretion near base------------------------	8 (?)	
2. Volcanic ash lens, maximum thickness-	12	
1. Shale, as above----------------------	5	
Creekbed		
Total section	54 (?)	6

Note: This is a composite section from two adjacent exposures. The exposure nearest the river includes beds 4-6. The other exposure, which is slumped on top, shows beds 1-4. There is some doubt as to the proper interval between the lower bentonites and the top of the ash lens, as the bentonite is poorly exposed, and the amount of slumping difficult to determine.

Detailed section of Oacoma zone and adjacent beds, about $\frac{3}{4}$ mile above mouth. Thicknesses estimated. SE$\frac{1}{4}$ Sec. 21, T. 20 N, R. 78 W.

	Feet
<u>Verendrye zone</u>	
3. Shale, dark brownish gray, weathers to gumbo-----------------------------	12
<u>Oacoma zone</u>	
2. Shale, gray, non-siliceous except at base. Includes 11 distinct bentonite beds--------------------------------	5
<u>Agency zone</u>	
1. Shale, light gray, siliceous--------	5
Creekbottom	

light gray shales are notably more resistent than the thin, bentonitic, darker beds and the zone accordingly is conspicuously banded in the outcrop. Weathering and erosion of these beds produces a stair-step effect in the outcrop, the position of the treads being determined by the position of the thin bentonitic clays and that of the lifts apparently by the distance into the outcrop to which the bentonitic clay has been weathered."

Black manganese concretions are characteristic of the zone south of Great Bend, but are said to be much less abundant north of that place. They are absent in the area under consideration except in a few outcrops at the extreme northern edge.

The Oacoma zone crops out along the Missouri from Charles Mix County, north to the mouth of the Moreau River. On the basis of microfossils, it has been identified as far east as Yankton, and from well cuttings in Todd and Pennington Counties in the western part of the state.

This zone of alternating light and dark shale overlying the siliceous Agency zone had previously been observed by Russell in Potter County (page 4), where he gave it the designation "bed LD."

The physiographic expression of the Oacoma zone in this area is a series of steps above the shelf which develops on the top of the Agency. These steps, which range from 5 to 13 feet in total height, are usually more or less covered with gumbo. Bones of marine reptiles are frequently observed on the surface. The outcrop is surther characterized by the presence of small selenite fragments scattered over the surface.

The thickness of the Oacoma is reported to vary from 20 to 46 feet over the area of outcrop. Both Russell and Searight assign 30 feet to the zone in Potter county, but as shown below, this figure is believed to be excessive.

The lithology of the Oacoma as it appears in this area can best be shown by a study of several detailed sections. It consists of a series of thin bentonite beds, usually 10-13 in number, separated by shale which grades from light gray and siliceous at the base to dark brownish gray and non-siliceous at the top. It is the tendency of the present workers to limit the Oacoma in the area under consideration to this bentonite zone. This gives a range of from 5 feet at Steamboat Creek (Table II) to 12 feet 7 inches in Dewey County, across from old LeBeau (Table V). The lowest zone of large manganese concretions typical of the overlying Verendrye zone usually occurs within 20 feet of the top of the Agency.

TABLE III

<u>Succession of beds, Oacoma zone, exposed at type locality of Agency shale, west end of Forest City Bridge, eastern Dewey County, South Dakota.</u>

Detailed section on hillside in line with end of bridge, Sec. 1, T. 12 N., R. 31 E.

	Feet	Inches
<u>Verendrye zone</u>		
22. Shale, dark gray, non-siliceous. Dries yellowish gray and weathers to gumbo---------		
21. Lowest zone of persistent manganese concretions------------------------------------		4
20. Shale, as above, but containing small, 1-2 inch concretions which are gray inside but irridescent or purplish on outside. Clam?--------- -----------------------------	11	11
<u>Oacoma zone</u>		
19. Bentonite, impure-----------------------------		¼
18. Shale, dark gray, non-siliceous-------------	1	9¼
17. Bentonite-------------------------------------		½
16. Shale, dark gray, non-siliceous-------------	1	
15. Bentonite, very impure-----------------------		1
14. Shale, gray, very slightly siliceous---------		8
13. Bentonite-------------------------------------		1½
12. Shale, gray, slightly siliceous. Weathers yellowish gray------------------------------		7½
11. Bentonite---------------- -----------------		½
10. Shale, greenish gray, bentonitic, slightly siliceous-------------------------------------		5½
9. Bentonite, impure-----------------------------		½
8. Shale, gray, slightly siliceous--------------		8
7. Bentonite--------------------------------------		½
6. Shale, light gray, slightly siliceous-------		4
5. Bentonite--------------------------------------		¼
4. Shale, greenish gray, bentonitic, gritty----		8
3. Bentonite--------------------------------------		¾
2. Shale, light gray, siliceous-----------------	1	5
1. Bentonite--------------------------------------		2
Oacoma Total thickness	8	5

<u>Agency shale zone</u>

Shale, light gray, siliceous, containing rusty concretions within 3 inches of top.

TABLE IV

Succession of beds, Swift Bird Creek, eastern Dewey County, South Dakota.

Detailed section of Oacoma zone, south side of valley, NW$\frac{1}{4}$ Sec. 9, T. 13 N, R. 31 E.

		Feet	Inches
Verendrye zone (?)			
15.	Shale, gray, non-siliceous		
14.	Concretions zone. Small, gray inside, irridescent or purple outside---------		1$\frac{1}{2}$
13.	Shale, gray, non-siliceous------------		8
Oacoma zone			
12.	Bentonite------------------------------		$\frac{1}{4}$
11.	Shale, gray, non-siliceous, not platy-		11$\frac{1}{2}$
10.	Bentonite, upper part impure----------		2
9.	Shale, very slightly siliceous, light gray to yellowish gray, platy---------	3	6
8.	Bentonite------------------------------		1
7.	Shale, light gray, very slightly siliceous-----------------------------------		4$\frac{3}{4}$
6.	Bentonite------------------------------		1
5.	Shale, light gray, very slightly siliceous-----------------------------------		7
4.	Bentonite, impure---------------------		$\frac{1}{4}$
3.	Shale, light gray, slightly siliceous-		4
2.	Bentonite------------------------------		$\frac{3}{4}$
	Total thickness----	6	2$\frac{1}{2}$

Agency shale zone

1. Shale, light gray, siliceous. Breaks into large flakes.

TABLE V

Succession of beds, Dewey County, South Dakota, opposite site of Old LeBeau.

Detailed section of Oacoma zone, SE$\frac{1}{4}$ Sec. 33, T. 16 N., R. 31 E.

	Feet	Inches
Verendrye zone		
27. Shale, gray, weathers into fine flakes rather than to gumbo. Contains many white and black manganese concretions----		
Oacoma zone		
26. Bentonite--------------------------------		½
25. Shale, dark gray, non-siliceous, weathers into small flakes-----------------------		3½
24. Bentonite--------------------------------		½
23. Shale, as above--------------------------		11
22. Bentonite--------------------------------		¼
21. Shale, as above--------------------------	1	7
20. Bentonite--------------------------------		¼
19. Shale, as above--------------------------		11½
18. Bentonite, impure------------------------		3
17. Shale, gray, dries light gray, flaky, very slightly siliceous-----------------------		9
16. Bentonite--------------------------------		½
15. Shale, as above, containing zone of manganese concretions up to 4-6 inches in diameter---------------------------------		8
14. Bentonite--------------------------------		¼
13. Shale, as above--------------------------	1	10½
12. Bentonite--------------------------------		½
11. Shale, as above--------------------------		4½
10. Bentonite--------------------------------		½
9. Shale, as above--------------------------	1	2½
8. Bentonite--------------------------------		½
7. Shale, as above--------------------------		2
6. Bentonite, impure------------------------		2
5. Shale, light gray, breaks into large plates, more or less siliceous--------------------		10
4. Bentonite--------------------------------		¼
3. Shale, light gray, siliceous, breaks into large plates---------------------------	2	1½
2. Bentonite--------------------------------		1
Total thickness Oacoma zone	12	7
Agency shale zone		
1. Shale, light gray, siliceous, breaks into large plates---------------------------		

As stated before, the contact of the Oacoma and the underlying Agency is believed to be conformable. Despite the variations in thickness of the Oacoma zone in this area, the contact with the Verendrye is also thought to be gradational. The few feet variation in thickness is likely due to differences in rate of deposition, and in the few cases where the number of bentonite beds is sharply reduced may be due to the dissemination of the bentonite through the shale at the time of deposition. The Oacoma is therefore regarded in this area as a transition formation between the siliceous Agency zone to the non-siliceous Verendrye zone.

<u>Verendrye zone</u>: The uppermost zone of the Sully member has been called the Verendrye by Searight (page 25) from exposure near the Verendrye monument, at Ft. Pierre, Stanley County, South Dakota. It includes the beds between the top of the Oacoma and the base of the bentonitic lower Virgin Creek Member.

The Verendrye beds consist of light to medium dark gray shale which contains large, flat, iron-manganese concretions in more or less well defined layers. These may reach a diameter of several feet, but are usually six inches or less in thickness. The typical concretions are usually gray on the interior, but weather to a purplish black on the surface. A few white or buff limestone concretions may be found near the base of the formation, especially in the north part of the area.

The shale weathers first to chips of gray shale and then to brownish gray gumbo. The outcrop may show stepping, though less pronounced and on larger scale than that found in the Oacoma zone. Near the middle of the formation in this area is a poorly defined zone of light gray shale which weathers to small silvery flakes resembling that in the lower Virgin Creek member. This may correspond to a similar zone noticed by Searight (page 26) at Wendte, Stanley County.

The Verendrye crops out along the Missouri Valley from Gregory County, north nearly to Mobridge, northwestern Walworth County.

At only one place within the area has a definite bentonite bed been noticed in the formation, though from the stepped and banded nature of the outcrops, and from the tendency of the formation to weather to gumbo, it is likely that it contains much disseminated bentonite. The two bentonite streaks reported in the upper 20 feet of the formation at Whitlock's Crossing by Searight (page 28) are placed by the present workers in the lower Virgin Creek member.

The contact between the Verendrye and the base of the Virgin Creek is not well exposed in this area. It is marked in a general way by springs, selenite fragments, and the lowest bentonite streaks. From observations in the northern part of the area, and along the Moreau River west of the area mapped, the base of the Virgin Creek appears to lie about 10-12 feet below the lowest conspicuous pair of bentonites, at which point the highest Verendrye concretions appear. Since these bentonites form the next highest horizon upon which mapping might be done, an effort has been made to determine the interval from the top of the Agency zone to the lowest pair of bentonites in the Virgin Creek. This interval appears to increase from about 100 feet at Swan Creek and 109 feet at Brown's Creek to 124-128 feet near and south of Cheyenne Agency. The actual thickness of the Verendrye zone therefore varies from about 90 to 100 or 110 feet within the area under consideration, apparently thinning toward the north. Russell assigned a thickness of 110 feet to the beds including the dark brown or purplish-black ferruginous concretions in Potter County, but Searight, who included the lower bentonites mentioned above, used 130 feet as the thickness at Cheyenne Agency.

Virgin Creek Member

The Virgin Creek member was named by Searight (page 35) from exposures on Virgin Creek, about one and one-half miles south of Promise, northeastern Dewey County. It is defined as including all beds between the Verendrye zone of the Sully member and the highly calcareous, chalky beds of the overlying Mobridge member.

The outcrop of the Virgin Creek has wide distribution along the Missouri Valley from Charles Mix and Gregory counties north nearly to the North Dakota line. In the area under consideration it forms the upper parts of the breaks and the uplands adjacent to them, and likely extends at least ten miles back on either side of the river. It has also been identified by Searight in parts of Nebraska, North Dakota, Montana, and around the Black Hills.

Lithologically, the Virgin Creek member is divided into an upper and a lower division. Because of the proximity of this area to the type locality, and because any further mapping in the area will require the use of these divisions, they will be discussed separately in this report, and several detailed sections, including part of the type section, will be given.

Lower Virgin Creek: This zone, as exposed at the type locality, includes slightly over 80 feet of gray shale which breaks down into small silvery flakes and contains many thin bentonite beds. Russell (pages 3,4) in describing the beds immediately overlying his iron-manganese concretionary zone in Potter County, noted a 20 foot zone of small white or bluish white concretions, peculiarly cracked or chipped on the surface, and with an oolitic structure. He termed this the "OO" bed. This zone is conspicuous over most of the area mapped during the past summer.

North-South Section of Upper Pierre
Dewey-Walworth-Potter
Counties

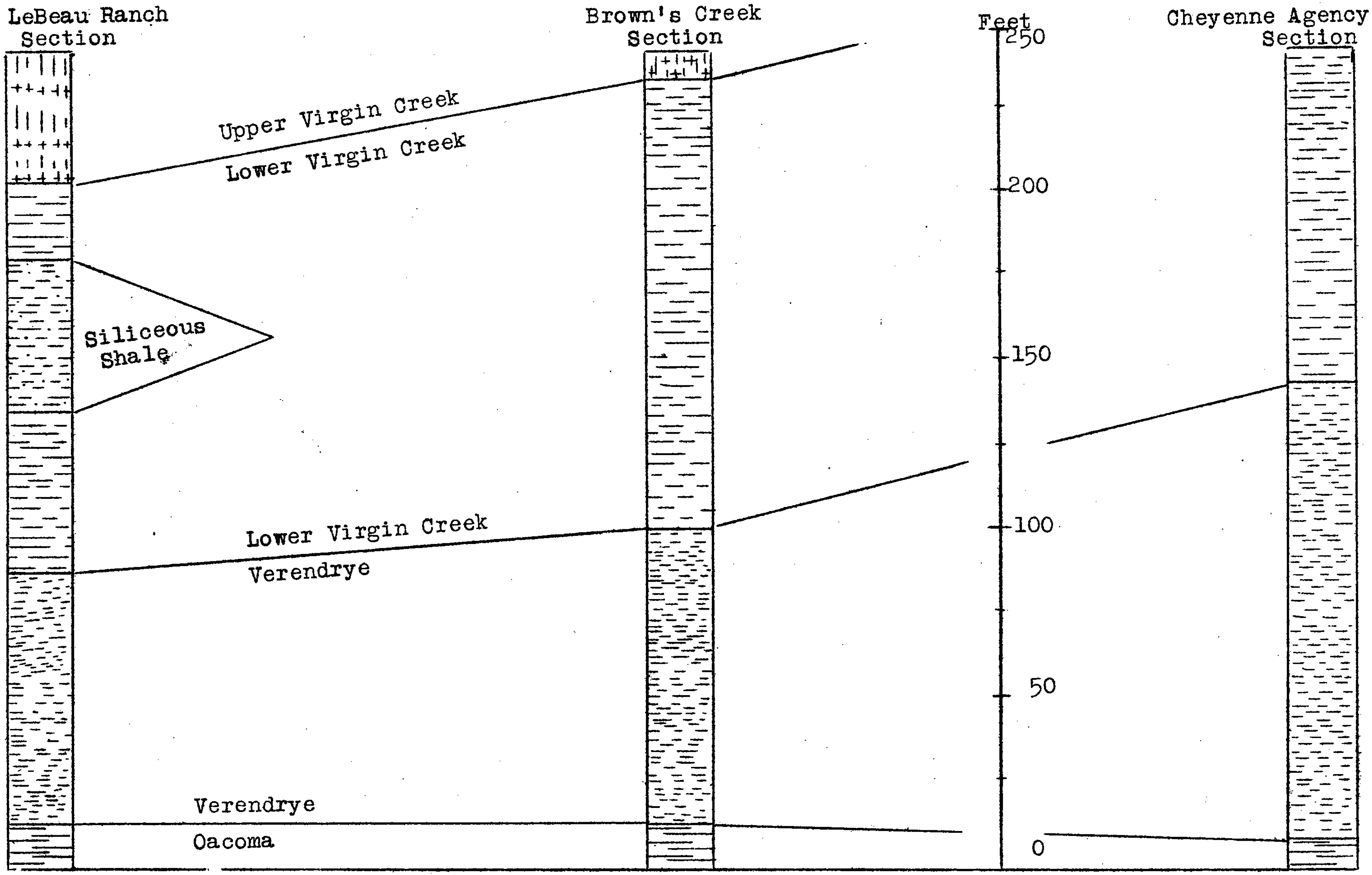


TABLE VI

Succession of beds exposed in valley of Brown's Creek, western Potter County, South Dakota.

Intervals measured by plane table survey.

	feet
Pleistocene and Recent	
Silt, thin gravel and erratics	10
Upper Virgin Creek	
Shale	13
Shale, golden calcite septaria at top	10
Shale, cinder-like concretions at top (possibly in part lower Virgin Creek)	35
Lower Virgin Creek	
Shale	5
Shale, bentonite at top	2
Shale, zone of gray concretions at top	102
Shale, bentonite at top and bottom of zone	1
Shale, pair of bentonites at base	14
Shale	9
Total thickness	133
Verendrye	
Shale	88
Oacoma	
Banded shales	12
Agency	
Shale, light gray, siliceous	

Field observations have also shown that two pairs of bentonite beds, roughly 20 feet apart, occur near the base of the Virgin Creek member, and that these oolitic concretions occur between, and to some extent above the bentonites. This series of beds, including the bentonites and the oolitic concretions does not appear in the type section south of Promise.

In tracing the lower Virgin Creek westward along the Moreau River, a high bluff was discovered about eight miles east of Promise which shows a complete section from below the lower pair of bentonites near the base of the member, up to and including many of the beds included in the lower part of the type section just south of Promise (See tables VII and VIII).

A composite section combining the sequence of beds eight miles east of Promise with the series one and one-half miles south of town, shows the actual thickness of the Lower Virgin Creek member in the type area to be about 145 feet. (Beds 27 to 31, table VI are without doubt the same as beds 16 to 20, table VIII). A thickness of 133 feet is tentatively assigned to the lower Virgin Creek in the valley of Brown's Creek (table VI).

The most striking feature of the lower Virgin Creek is the large number of bentonite beds. At the type locality, Searight has recorded eleven beds in the lower zone and three in the upper part. The section exposed eight miles east of Promise contains at least seven beds below those in the type section, so that the total number in the lowest zone is at least 18 beds. Fragments of selenite associated with the bentonite are characteristic of the basal part of the formation.

The concretions in the lower Virgin Creek are of several varieties. The oolitic concretions which have already been mentioned usually vary from two to four inches in diameter and are not over two inches thick. They are slow to break up upon weathering, and are prone to migrate down the slope for considerable distances. The zone is at least 20 feet thick in places, and the top of it has been observed as much as 50 feet above the lower bentonites just west of Cheyenne Agency. Farther north in the area they have been found between the lower pairs of bentonites, so that within this immediate area the zone has a vertical range of at least 50 feet, The use of the OO bed as a key horizon therefore does not seem advisable.

Gray concretions which weather brown or black, similar to those in the Verendrye, are found scattered throughout the lower Virgin Creek, though they are not numerous. In isolated outcrops they appear to lie in bands or zones, but their lateral persistence has not been checked. In size they range from two inches or less to huge log concretions six to eight inches thick and several feet in greatest diameter.

TABLE VII

Succession of beds, ranch of Lloyd LeBeau, 8 miles east of Promise, northeastern Dewey County.

Detailed section of Lower Virgin Creek Member measured by plane table from bluff along north side of Moreau River, Sec. 9, T. 16 N., R. 30 E.

	Feet	Inches
Lower Virgin Creek Member		
37. Shale, gray, soft, non siliceous, weathers yellowish gray. Exposure capped by gravel	31	2
36. Bentonite		$1\frac{1}{2}$
35. Concretion layer, brown to black nodules		$2\frac{1}{2}$
34. Shale, medium gray, non-siliceous, containing numerous thin layers of $\frac{1}{2}$" to 1" concretions, as above. Shale weathers to brownish gray gumbo; some very bentonitic becoming more siliceous toward base	12	10
33. Bentonite		2
32. Shale, light gray, siliceous	2	10
31. Bentonite		$\frac{3}{4}$
30. Shale, as above		6
29. Bentonite		$\frac{1}{2}$
28. Shale, as above		3
27. Bentonite		$\frac{1}{4}$
26. Shale, as above	2	11
25. Bentonite		1
24. Shale, as above	1	
23. Bentonite		$\frac{1}{2}$
22. Shale, as above		2
21. Bentonite		$\frac{1}{2}$
20. Shale, as above	3	5
19. Bentonite		$\frac{1}{2}$
18. Shale as above, middle part obscured	24	
17. Bentonite		$\frac{1}{4}$
16. Shale, as above	8	6
15. Bentonite		$\frac{1}{4}$
14. Shale, as above	1	6
13. Bentonite		$\frac{1}{2}$
12. Shale, as above	3	11
11. Concretion zone. Concretions 6"-8" thick and up to several feet across		8
10. Shale, clayey, more or less siliceous, zone of small concretions 1 foot below top	17	3
9. Bentonite, split in some places on outcrop		4
8. Shale, as above	3	$10\frac{1}{2}$
7. Bentonite		4
6. Shale, as above	12	2
5. Bentonite		$\frac{3}{4}$
4. Shale, as above	5	$2\frac{3}{4}$
3. Bentonite		1
2. Shale, clayey, dark when wet, light dry, more or less siliceous, makes small flakes upon weathering	11	5
Verendrye (?) zone.		
1. Concretion zone, intermittent		8
Shale, light gray	4	4
Creek bed		

TABLE VIII

Detail of lower part of the type section of the Virgin Creek member of the Pierre Formation.

Single exposure on Virgin Creek, 1.5 miles south of Promise, northeastern Dewey County, South Dakota. Measured by plane table.

	Feet	Inche
Upper Virgin Creek Member		
40. Shale, gray, weathering to brownish gray gumbo		
39. Shale, same, containing large white or light buff limestone concretions----------------------	17	4
38. Shale, same, containing wormeaten concretions and Serpula (?), but no large concretions-------	16	3
Lower Virgin Creek, upper zone		
37. Bentonite--------------------------------------		¼
36. Shale, gray. Dark gray and muddy when wet, dries yellowish gray, very hard, and gritty-----------	12	6
35. Bentonite--------------------------------------		1
34. Shale, gray. Dark and very soft when wet, dries light gray, very hard, and gritty; containing scattered limestone septaria whose cracks and surface are coated with delicate gypsum crystals	5	5
33. Bentonite--------------------------------------		2
32. Shale, as above--------------------------------	7	7½
31. Shale, same, containing frequent white limestone concretions 1" to 2" in diameter----------------		2
30. Shale, gray, partly bentonitic, slightly siliceous	3	6
29. Shale, gray, slightly siliceous, joint planes stained reddish brown. Top contains zone of white limestone concretions, 1" to 1' in diameter-----	7	4¾
Total upper zone-------	36	10½
Lower Virgin Creek, lower zone		
28. Bentonite--------------------------------------		½
27. Shale, gray, more or less siliceous-------------	2	3½
26. Bentonite--------------------------------------		½
25. Shale, as above--------------------------------	2	7
24. Bentonite--------------------------------------		1½
23. Shale, same------------------------------------		2
22. Bentonite--------------------------------------		½
21. Shale, gray, mostly siliceous, occasional small limestone concretion at base------------------	1	2
20. Bentonite--------------------------------------		½
19. Shale, bentonitic, non-siliceous, purplish or iridescent stain on partly weathered fragments---		7¾
18. Bentonite--------------------------------------		¾
17. Shale, as above--------------------------------		1½
16. Bentonite--------------------------------------		1

<u>Lower</u> <u>Virgin</u> <u>Creek</u>, lower zone, con't.

	Feet	Inches
15. Shale, as above	3	2½
14. Bentonite		1
13. Shale, as above		4½
12. Bentonite		1/8
11. Shale, as above		7 1/8
10. Shale, as above, containing intermittent layer of rusty concretions 2" to 3" thick, and 6" to 8" in diameter		3
9. Shale, alternating beds of siliceous and non-siliceous, the latter having the irridescent coating	3	1
8. Shale, non-siliceous, containing 1" by 3" iridescent concretions		1
7. Shale, alternating siliceous and non-siliceous	3	
6. Bentonite, impure		½
5. Shale, siliceous, light gray	8	8
4. Bentonite		¾
3. Shale, very slightly siliceous, irridescent	1	3
2. Bentonite		¾
1. Shale, more or less siliceous, light gray, containing zone of manganese concretions about 5' above creek bed	15	9½
Total lower zone exposed	45	8½

Two other types of concretions are found at the type locality. A layer of white limestone concretions varying greatly in size, lies about 50 feet above the creek bottom. In the upper zone of the Lower Virgin Creek, between the two conspicuous bentonite beds, there occur grayish white limestone septaria, the cracks and surface of which are coated with delicate selenite crystals. As these break down rapidly upon weathering, they are not found except on the freshest exposures.

Another feature of the Lower Virgin Creek in this area and farther north is the siliceous nature of some of the outcrops. In the type exposure, the lower 40 feet are composed of alternating siliceous and non-siliceous beds. A small exposure about two miles southeast of Promise is so uniformly as to strongly resemble a weathered Agency outcrop. The basal 100 feet of the formation as exposed eight miles east of Promise is largely siliceous. Within the area mapped, the most siliceous zones appear to lie between the lower two pairs of bentonites. From the observations of the past summer, it appears that this area may represent a transitional zone between non-siliceous shale to the south and siliceous shale to the north. The alternation of siliceous and non-siliceous beds, and the spotty areal distribution of the siliceous zones would be typical of such a transition.

Upper Virgin Creek: This division of the member is usually not well exposed in this area as it occurs high on the ridges and weathers rapidly to gentle gumbo slopes. The gumbo frequently creeps down over much of the lower part of the member also.

The lower part of the upper Virgin Creek consists of gray shale containing three types of small, diagnostic concretions. One consists of small gray or brown concretions which weather nearly white on the surface, and are perforated with many small holes. Russell (page 3,4) noticed the "worm-eaten" appearance of these concretions, and designated the zone as "bed WE". A second type includes small, cylindrical concretions, grayish in color, with a soft core which weathers out, leaving hollow cylinders often termed "Indian Beads". These have doubtfully been identified as worm tubes, Serpula (?) wallacensas Elias. Their relation to some type of plant seems more likely. The third group are small, bluish gray concretions containing the fossil remains of crabs. Of the three types, the latter are the most spotty in their distribution, due no doubt to the gregarious nature of the crabs.

Large white or buff limestone concretions also occur near the base of the upper division of the Virgin Creek, and form a conspicuous feature on the bare outcrops along the lower Moreau and Virgin Creek. A zone of large gray concretions is said by Searight (page 37) to be present near the top of the Virgin Creek over wide areas. These are frequently septarian, with the cracks filled with yellow calcite. Such concretions have been noted frequently over the area mapped, but measurements of the interval from the top of the Agency to the concretions suggest that they may not be confined to one zone. Their value as a horizon marker is therefore doubtful. Very highly fossiliferous concretions of this type, containing the Sage Creek fauna, are found around the Black Hills and in parts of North Dakota and Montana, and as far east as Midland, South Dakota. Black concretions which break down to small cinder-like fragments have been observed near the base of the upper zone of the formation along Brown's Creek (Table VI).

The thickness of the upper Virgin Creek was not determined in the area under consideration. Searight (page 39) reports a thickness of 100 feet at the type locality.

Mobridge Member

This member was named by Searight (page 44) from exposures in southeastern Corson County, across the Missouri from Mobridge. It includes the highly calcareous shale and chalk beds lying between the Virgin Creek and Elk Butte members. The shale is gray or bluish gray in fresh exposures, but weathers rapidly to a buff clay. The Mobridge member is not known to be present along the Missouri River breaks in the area mapped, though it is likely that small outliers may be found in such elevations as the Patchskin Buttes, just west of the area. It is present over much of the northwestern and southwestern parts of Dewey County.

The thickness of the member at Mobridge is 136 feet. Variations of from 90 feet in Charles Mix county to 230 feet in Ziebach county are reported by Searight.

Elk Butte Member

This member includes a thick series of gray shales lying between the calcareous Mobridge member of the Pierre and the base of the Fox Hills sandstone. It was named by Searight (page 50) from exposures at Elk Butte, Corson County, South Dakota. The member lies too high stratigraphically to be found in this area.

GLACIAL AND POST-GLACIAL DEPOSITS

The unconsolidated surficial deposits are the result of deposition during the Pleistocene or Ice age, and the Recent, or post-glacial period. Although an early advance of the great ice sheet is believed to have covered the entire area under consideration, deposits made by it have been largely removed by erosion. A later advance of the ice covered the region east of the Missouri with a heavy mantle of glacial till which has been little eroded except close to the river and along the major tributaries. Thicknesses of drift up to about 75 feet are reported in some of the artesian wells in the area.

Except on steep slopes where erosion has been rapid, much of the area is mantled by a deposit of silt. This is probably in large part water laid, but some of it may be wind deposited, in which case it should more properly be referred to as loess. The silt and loess were probably laid down in front of the retreating ice sheet. In some cases a thin deposit of gravel and coarse sand underlies the silt, suggesting that coarser materials were deposited when the melting ice was close, and that as the ice retreated, the materials deposited became increasingly fine. Large boulders of igneous and metamorphic origin are frequently observed in or at the base of the silt. The exact way in which these were transported has not been determined. It has been frequently suggested that they were floated in on ice fragments at the time the silt was laid down. It is also possible that many of them are residual boulders from the earlier ice advance.

VI. STRUCTURE

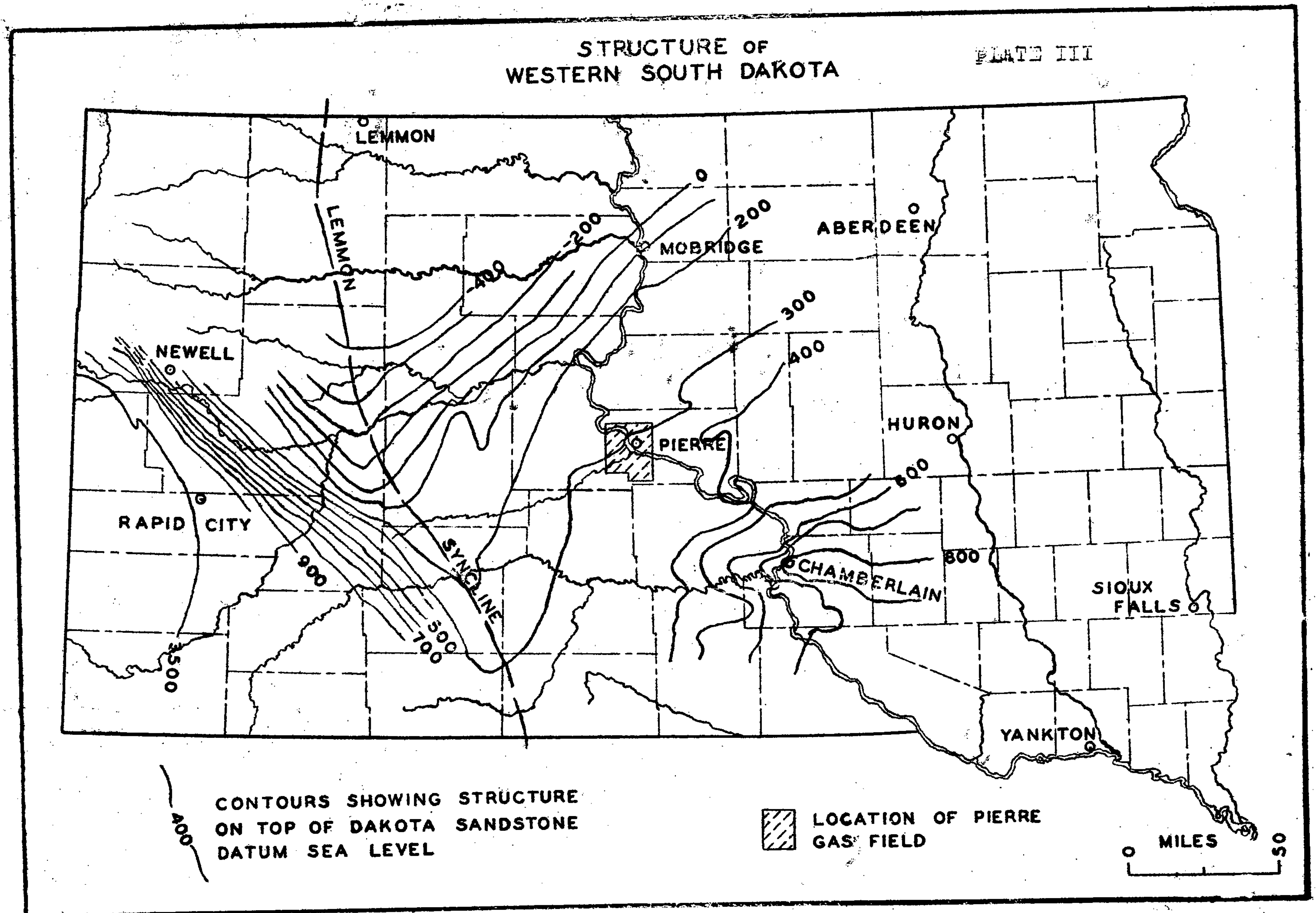
GENERAL STRUCTURE

The dominant structure of west central South Dakota as determined on the top of the Dakota sandstone is the broad, northwest plunging Lemmon syncline (See plate III). The axis of this trough lying between the Black Hills uplift and the crystalline area in the eastern part of the state, runs nearly north -northwest through Kadoka, Philip and Lemmon. The area covered by this report lies well up on the east flank of the structure, just below the edge of a broad structural terrace. The regional dip of the Dakota sandstone is northwest about 11 feet to the mile.

The surface beds in the area appear to be dipping gently to the north, but less steeply than the Dakota formation. This suggests an increase in the interval between the top of the Dakota and the top of the Agency, both to the west and to the north. A known thickening of these beds toward the Black Hills accounts for the reduction in westward dip at the surface. Evidence outside of the area indicates that there must be material thickening of one or more of these same beds northward. The Dakota lies about 160 feet lower at Cheyenne Agency than it does at Pierre, but the top of the Agency lies 90 to 100 feet higher at the Agency than at Pierre. An increase in interval of about 250 feet must therefore be accounted for. Further divergence is believed to occur between Cheyenne Agency and the north edge of the area mapped. Increase in thickness of the Agency shale member alone probably does not account for more than a fraction of the increased interval. Although exact correlation between the Agency and Gettysburg well logs is not possible, study of these two records suggests the possibility that the Gregory member is considerably thicker here than at the northernmost exposure on Crow Creek (Page 10). If this does not account for the entire increase in interval, the beds between the base of the Pierre and the top of the Dakota must also thicken northward.

Absence of detailed information as to the variation in thickness of the rocks between the Dakota and the upper Paleozoic limestones, for instance, makes it possible that the structure on the limestone is somewhat different from that on the Dakota sandstone. Although the evidence is meager, it seems likely that any thickening of these intervening beds would be toward the north or west, which would merely serve to accentuate the steepness of the east flank of the syncline and reduce the dip on the west flank. Any steepening of the dip is of utmost importance is interpreting the significance of the observed surface structures.

PLATE III


STRUCTURE OF
WESTERN SOUTH DAKOTA
LEMMON
LEMMON
0
-200
-400
200
300
400
600
800
900
500
700
3500
ABERDEEN
MOBRIDGE
NEWELL
PIERRE
HURON
RAPID CITY
SYNCLINE
CHAMBERLAIN
SIOUX FALLS
YANKTON
400
CONTOURS SHOWING STRUCTURE
ON TOP OF DAKOTA SANDSTONE
DATUM SEA LEVEL
LOCATION OF PIERRE
GAS FIELD
0 MILES 50

DETAILED LOCAL STRUCTURE

The local structure as determined on the top of the Agency shale is outlined on the accompanying map. Because the outcrops are limited to a narrow belt along the River, it has not been possible to close the structures in many cases. The contours, however, do give a good idea as to the magnitude and trend of the structural features. The elevation of the top of the Agency rises from about 1580 feet at the southern edge of the area to nearly 1640 feet in the area around Cheyenne Agency, then declines to about 1530 feet near the mouth of the Moreau, giving a structural relief of about 110 feet within the area. The contour interval used is 10 feet, as this outlines the features clearly, and permits closing some of the more pronounced structures. A five foot interval might approach the possible error in choosing some of the contacts, and at first glance, might give a false impression of the structural relief within the area.

Because of the strong topographical relief developed along the Missouri, there has been considerable slumping of the Pierre shale. The slumps are usually easily recognized because of their characteristic topography, and the lack of covering vegetation in the area; and the greatest care has been taken to obtain elevations on unslumped outcrops. The degree of success in selecting exposures may be judged from the concordance of elevations on both sides of the River, and from the uniform trend of the structures mapped.

The trend of the structural features outlined on the accompanying map is surprisingly uniform. In the southern and central parts of the area, the trend is almost exactly northwest-southeast, at right angles to the regional strike, and roughly parallel to the axis of the Lemmon syncline. In the northern third of the map, the trend swings slightly, and becomes roughly west - northwest, east - southeast.

Since the folding of the region is at right angles to the regional strike, the strike lines cross and recross the river many times, outlining an alternating series of low narrow noses and troughs, plunging northwest. Small domes are developed on some of the noses. Interpretation of the structures is difficult because of the absence of any data either east or west of the river breaks.

The largest single structure is outlined by the 1600 foot contour, including an irregular area about 10 miles across, with its center two or three miles northwest of Cheyenne Agency. Two or three elongate, northwest trending domes are located within this area. One lies just west of Cheyenne Agency, and extends both north and south of the river, the highest point observed being about two and one-half miles northwest of town. A second high lies just south of Swift Bird Creek, and although its western limits are not known, the highest point observed lies about five and one-half miles north-northwest of Cheyenne Agency. The third high lies north and east of Whitlock's Crossing. It is not completely outlined, as the area is largely covered with glacial till and terrace gravels. It may be a southeast extension of the Swift Bird Creek area. Although the 1600 foot contour may not close on the eastern side of the large structure, the total closure within the area appears to be about 30 feet. Closure on the individual domes is apparently between 10 and 20 feet.

The second most conspicuous area lies near the mouth of Swan Creek in the northeastern corner of the map. As the Agency lies very low in that area, the structure has been determined largely upon the base of the Virgin Creek member, and the thickness of the interval to the top of the Agency in that area (100 feet) subtracted from the elevations. The closure may not exceed 15 feet.

Several smaller highs, with closures of about 10 feet were found. Two of these may be seen in the extreme southwestern part of the map, south of Stove Creek, in Armstrong County. Another occurs near the center of the area, on the west side of the River, across from Swedes Draw, and a fourth is located in sections 13 and 14, T. 15 N., R. 31 E.

There has not been sufficient careful mapping combined with drilling in the northern Great Plains states to enable definite conclusions as to the possible changes in these structures with depth. The two most likely possibilities are either that they retain about their same magnitude with depth, or that they increase in sharpness below, and become flattened in the soft Cretaceous shales. It is not likely that they die out with depth.

If they retain the same magnitude, the increased regional dip at the horizon of the Dakota is important. An increase in dip of even 10 feet to the mile would tilt the smaller domes so that they would lose their closure and appear only as noses. Probably only those in the area around Cheyenne Agency and at Swan Creek would still close on the Dakota, and with any further increase in dip below that level, even those might be destroyed.

If, on the other hand, as is quite common in areas overlain by thick shales, the structures increase in intensity with depth, the closure in the lower beds may be several times as great as it appears at the surface. Only test drilling in a carefully mapped area will give the answer to this problem.

VII. OIL AND GAS POSSIBILITIES

The presence of gas in many of the local artesian wells has already been mentioned. Apparently the first well in this immediate area to encounter gas was the one drilled at the Cheyenne Agency about 1900. Gas was reported from the Carlile shale and again from the Graneros. At the time of drilling, it was reported that the well "contains much illuminating gas, which was encountered by the eight inch casing and amounts to about 2400 cubic feet a day."[1] It was not recorded whether additional gas was present in the Dakota sandstone.

Numerous other wells in the area have encountered gas, as indicated on the accompanying map.[2] Only in the Wilson and Genzler wells is the gas known to have been utilized for domestic purposes, although the amount escaping from several of the other wells would certainly justify development.

The source of this gas has not definitely been established. If it is shale gas, as has generally been supposed, it is disseminated through the shale and small quantities should be yielded almost indefinitely. The finding of gas in sandy or limy zones in the shale during drilling has led to this belief, although this does not preclude the idea that all the gas has come from a deeper source and has been trapped in such porous zones. The fact that in some instances, gas has not been noticed until the newly drilled well starts flowing has suggested that the gas may be chiefly in the sandstone, and that it is only brought to the foot of the well by the movement of water in that direction. Reports that gas is no longer noticed in some wells that have ceased to flow have supported this theory. If this is correct, it offers another strong argument for control of flowing wells; to conserve the gas as well as the water supply.

The fact that the gas-producing wells are more or less closely grouped, not only in this area, but in the Pierre gas field as well, has suggested a third hypothesis, namely that the accumulation of gas may be due at least in part to structure. Whichever theory is correct for the gas encountered in or above the Dakota sandstone, it nevertheless is true that the most favorable locations for development of deeper supplies are on the structurally high areas.

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1. N. H. Darton, <u>Geology and Underground Water Resources of the Central Great Plains</u>, United States Geological Survey, prof. Paper 32, 1905, p. 214.
2. For location of additional wells in Potter County, see also W. L. Russell, <u>The Possibilities of Oil and Gas in Western Potter County</u>, Report of Investigations No. 7, S. Dak. Geol. and Nat. History Survey, Dec.1930. Figure 2.

In determining the oil and gas possibilities of any area, it is necessary to consider four questions. First, are the source rocks present from which oil or gas could form; secondly, are suitable reservoir rocks available to receive these products; third are structures present which would collect them in small areas within the reservoir rocks; and fourth, have the reservoir rocks been flushed out by circulating artesian water.

It is generally believed that oil originates in marine sediments containing bituminous material. Black shales are probably the most common source rocks, but frequently sandstone or limestone may carry much disseminated bituminous material. Russell (page 10) has suggested that the thin black shales in the Carboniferous rocks of this region might serve as source rocks.

There are several possible reservoir rocks in the local geologic section. It is possible that gas or even oil may be trapped in some of the structures in the Dakota group, but these formations have been so thoroughly drilled for water that the chance of their containing any material amount of oil seems remote. It does seem quite probable, however, that increased yields of gas from the Dakota or overlying formations might be found in wells drilled on local structures. The next possible oil reservoir is in the sands of the Sundance formation.

The most promising reservoir rocks in the state belong to the upper Paleozoic system. The Minnelusa formation, contains thin sands in this region. As these are likely more or less discontinuous, the formation offers more promise than it does farther west where the thick sandstone offers opportunity for more complete artesian circulation. The underlying Pahasapa limestone, which is probably over 500 feet thick in this area, should be thoroughly tested. Although it is the oldest Paleozoic formation of which we have record in the central part of the state, it seems likely that older limestones are present. Any test should be planned to continue well into the Cambrian beds unless pre-Cambrian rocks are encountered immediately below the Mississippian limestone. The total thickness of sediments to be tested is estimated at between 4000 and 5000 feet (Plate I, page 37).

The structures on the Agency shale appear to have closures as great as 30 feet, but whether this continues with depth is not known. It has already been suggested that because of the increased dip at the elevation of the Dakota sandstone, these high areas may appear there only as small noses or terraces on the flank of the broad Lemmon syncline. On the other hand, it is possible that the structures are sharper at greater depths, and flatten out somewhat in the thick Cretaceous shales. In either event, they appear to be the most favorable locations for gas and oil accumulation within the area under consideration, and therefore offer the best locations for test wells.

Water associated with oil is always highly mineralized. In areas where the circulation of underground water is sufficiently vigorous to flush out the salt water, it is apparently also capable of either flushing out the oil or preventing its accumulation. For this reason, the exact nature of the sands in the Dakota group is significant. If the Dakota and the Lakota are always two separate and continuous sandstones underlying much of the state, they should be well flushed out by circulating ground water entering them at their outcrops around the Black Hills and beneath the glacial drift in the eastern part of the state. But as previously mentioned, study of records of many artesian wells has suggested that the sands in this group may be lenticular in nature, so that circulation is restricted, and perhaps nearly impossible in some zones and areas. The mineralized nature of the water from many of the wells also suggests that the flushing process is very slow and certainly not complete. This is the saltiest water in the state according to Guy G. Frary, State Chemist.

Water Analysis of Eitemeier Well
SE$\frac{1}{4}$ Sec. 19, T 121 N., R. 78 W.
State Chemical Laboratory
Guy G. Frary

	P.P.M.	G.P.G.
Total Solids	4963.0	289.7
Silica	13.0	0.76
Sulphate (SO_4)	None	
Chloride (Cl)	2564.0	149.7
Calcium (Ca)	18.0	1.05
Magnesium (Mg)	10.0	0.58
Alkalinity as $CaCO_3$		
Phenolphthalein	None	
Methyl Orange	628.0	36.65
Hardness as $CaCO_3$	86.5	4.96
Iron	0.3	
Manganese	None	
Fluoride	0.6	

Water Analysis of Wilson Artesian Well
SE$\frac{1}{4}$ Sec. 25, T. 122 N., R. 78 W., Walworth Co.
State Chemical Laboratory, Guy G. Frary

Total Solids	5219.0	304.7
Silica	15.0	0.88
Sulphate (SO_4)	None	
Chloride (Cl)	2696.0	157.4
Calcium (Ca)	17.5	1.02
Magnesium (Mg)	9.5	0.56
Alkalinity as $CaCO_3$		
Phenolphthalein	None	
Methyl Orange	634.0	37.0
Hardness as $CaCO_3$	84.0	4.82
Iron	0.7	
Manganese	None	
Fluoride	0.6	

Water Analysis of Fred Genzler Well
SE$\frac{1}{4}$ Sec. 12, T119N, R78W, Potter Co.
State Chemical Laboratory, Guy G. Frary

	P.P.M.	G.P.G.
Total Solids	5009.0	292.3
Silica	12.0	0.70
Sulphate (SO_4)	None	
Chloride (Cl)	2592.0	151.35
Calcium (Ca)	21.0	1.23
Magnesium (Mg)	11.0	0.64
Alkalinity as $CaCO_3$		
Phenolphthalein	None	
Methyl Orange	618.0	36.10
Hardness as $CaCO_3$	98.5	5.65
Iron	0.6	
Manganese	None	
Fluoride	0.6	

Water Analysis of Rabe's Artesian Well
Sec. 23, T. 117 N., R 79 W., Potter Co.
State Chemical Laboratory, Guy G. Frary

Total Solids	4962.0	289.5
Silica	12.5	0.73
Sulphate (SO_4)	None	
Chloride (Cl)	2584.0	150.9
Calcium (Ca)	34.0	1.98
Magnesium (Mg)	16.0	0.93
Alkalinity as $CaCO_3$		
Phenolphthalein	None	
Methyl Orange	588.0	34.32
Hardness as $CaCO_3$	152.0	8.87
Iron	0.4	
Manganese	None	
Fluoride	0.6	

Water under artesian head is encountered in the Sundance sands farther west, and even in the Standing Butte well, two water sands, one with "great water flow," were noted. The Sundance formation is so variable in nature that the oil possibilities of the formation should not be ruled out because of the above report.

The Minnelusa is an important water sand in the vicinity of the Black Hills. However, as the formation becomes much more shaly and limy to the east, it seems to carry much less water. In the Sta nding Butte well, again, supposedly fresh water was reported from near the base of the formation.

This same well had no report of water from the Pahasapa limestone. At the outcrop this formation is very cavernous, and an important aquifer, but the extent to which this is true under the plains is not definitely established. The Hunter no. 1 well, 20 miles north of Wall, Pennington County, reported fresh water from two "porous zones" in the upper 200 feet of the formation, but that well was within 55 miles of the outcrop. Circulation of water through solution channels would not be as likely to prevent or remove oil accumulation as the uniform circulation through a porous sandstone. It is not believed likely that artesian water will be encountered in the Pahasapa in this area.

The possibility of finding strong artesian flow in any of the formations underlying the Pahasapa appears to be remote.

Discussion of oil "shows" in other wells in the region can be nothing more than a reiteration of reports, some verified, others more or less doubtful. The Dakota is frequently reported as carrying some gas, and unverified reports are at hand of oil appearing periodically in some of the artesian farm wells. The Standing Butte well also reported an oil show at this horizon.

Oil shows are reported at the top of the Minnekahta, and both gas and tar in the Minnelusa formation in the Standing Butte well.

VIII. CONSIDERATIONS FOR DRILLING

Favorable areas: Although it has been pointed out in a previous chapter that none of the structures mapped in this area are sharp, there are three or four small domes which should be considered as the most favorable areas for test drilling. Three of these are located in the south central part of the area, and show the highest elevations encountered. The largest of these is seen to lie northwest of Cheyenne Agency. The second, and highest of the three, is located just south of the mouth of Swift Bird Creek, also in Dewey County. A third, less well defined high, which is perhaps an extension of the Swift Bird area, appears to center a mile or so northeast of Whitlock's Crossing, in Potter County.

A fourth definite structure is outlined at the mouth of Swan Creek, at the northeast corner of the area mapped, in Walworth County. Structurally, this high lies about 70 feet lower than those farther to the south. Several smaller structures are outlined which would certainly deserve testing if favorable results were obtained in testing any of the larger highs.

Only one of the gas-producing artesian wells in the area lies close enough to the outcrops mapped to permit a comparison of the structure with the quantity of gas encountered in drilling. The Cheyenne Agency well was located in the highest part of the region, structurally speaking, where the top of the Agency lies above 1600 feet, but it was actually located near the trough of a small syncline within that area.

Depth: The necessary depth for a test hole at any specific point will obviously be dependent upon the surface elevation at the chosen location, and the structure and thickness of the bedrock formations. The elevation of the top of the Agency Shale varies roughly from 1530 to 1630 feet within the area. Variation in the elevation of the Dakota is even greater, as previously noted (See Appendix viii). But of considerably more importance in estimating the depth to a given formation, is the surface relief of about 500 feet. Since the present topography in no way reflects the underground structure in this region, there is no geological advantage to locating a test on high ground, and several hundred feet of drilling can easily be saved by locating a test hole on low ground. In some parts of the area, a higher elevation may be sufficiently more accessible to justify drilling the additional footage.

Using the table of estimated thicknesses for this area (Plate I) it may be seen that a well started in the river bottoms, considerably below the top of the Agency shale, and encountering only a minimum of perhaps 250 feet of the Dakota group, might be expected to strike the top of the Pahasapa at about 2600 feet. On the other hand, a test hole on the upland, starting in the upper Virgin Creek member, and encountering a maximum of 500 feet of Dakota-Fuson-Lakota beds, would probably enter the top of the Pahasapa at somewhat over 3300 feet. Allowing at least 500 feet for the thickness of the Pahasapa and another 500 for any earlier Paleozoic formations, the total thickness of formations to be tested in this area is probably between 4000 and 5000 feet. Anyone planning test drilling should therefore be prepared to drill to at least 5000 feet.

<u>Transportation and communication</u>: The area is served by three railroads. On the north and west, the Milwaukee line from Aberdeen crosses the Missouri River at Mobridge, then swings down to Promise and LaPlant, then west to Dupree. The M. and St. Louis extends west from Norbeck through Hoven, and ends at Akaska. The southeastern side of the area is served by the Northwestern line extending west from Redfield to Gettysburg, then south to Pierre.

The principal highway across the area is U.S. 212, extending east-west from Gettysburg through Cheyenne Agency and LaPlant. Other roads in the area are merely trails, impassable in bad weather. The trail up the west side of the Missouri from a few miles west of Cheyenne Agency to the Moreau River School, near the mouth of that stream, and thence to Mobridge is being straightened and graded, and will presumably soon be passable at all times. On the eastern side of the river, graveled roads approach within a few miles of the river.

<u>Water</u>: Water will likely be needed for drilling until the Dakota sandstone is encountered. Water from this formation will flow if the test well should be located on the lowlands in the river valley. If a well is drilled on the upland, at some distance from the outcrop, there is a slight chance that some water might be encountered in the joints of the Agency shale. In any case, the Agency may "take" considerable water during drilling operations.

Water for drilling operations can be secured either from the Missouri River, or by impounding it in one of the small tributary valleys during the wet season. Such tributary streams as the Little Cheyenne and the Moreau could not be depended upon to yield water the year round, though infiltration wells dug in the bottoms along the Moreau would probably supply sufficient water.

APPENDIX

WELL RECORDS

Cheyenne Agency

Location: S.E.¼ Sec. 2, T. 12 N., R. 31 E., Dewey County, S.Dak.
Drilled: About 1900
Source: U.S.G.S. Professional Paper 32.
Elevation: 1537 feet.

	Thickness	Depth
Pleistocene and Recent		
Yellowish gravelly clay	21	21
Sandstone boulders and shale fragments	5	26
Pierre, Niobrara, Carlile, Greenhorn, Graneros		
Shale, hard	14	40
Shale, blue, firm	240	280
Shale, blue, soft	110	390
Shale, black	95	485
Shale, sandy	15	500
Shale, gray	15	515
Shale, hard	60	575
Shale, dark gray; gas at 650 feet	125	700
Shale, black, with some beds of hard sandstone	350	1050
Shale, blue	150	1200
Shale, dark gray; gas	111	1311
Dakota		
Limerock, soft, yellow	6	1317
Sandstone, white, flow	6	1323
Shale, brownish	14	1337

GETTYSBURG #2

Location: City of Gettysburg
Drilled: Norbeck & Company; 1924
Source: City Engineer
Surface Elevation: 2089.7

	Thickness	Depth
Pleistocene and Recent		
Soil, black	2	2
Clay, yellow	90	92
Pierre and Niobrara		
Clay, blue (may include some glacial till)	208	300
Shale, "Pierre"	264	564
"Supposed chalk rock" (Agency?)	60	624
Shale, "Pierre"	326	950
Carlile		
Shale, black, oily	486	1436

	Thickness	Depth
Greenhorn		
Cap rock, soft	5	1441
Cap rock, hard	11	1452
Cap rock, soft	8	1460
Graneros		
Shale, black, oily	151	1611
Shale, sandy	2	1613
Shale, black, oily	16	1629
"Supposed pyrites"	3	1632
Shale, black, oily	25	1657
A "tough shale"	10	1667
Shale, black, oily	63	1730
Shale, sandy	59	1789
Dakota Group		
Sand, water-bearing, with some streaks of shale	128	1917

FOX WELL

Location: S.W.¼ Sec. 11, T. 18 N., R. 76 W., Potter County.
Drilled: 1910-11
Source: Memory of Fred Hartman who worked on well.
Elevation: 2071. feet.

	Thickness	Depth
Pleistocene		
Clay, with gravel and water at 130. (May be shale below gravel	230	230
Pierre, Niobrara, Carlile, Greenhorn, Graneros		
Shale, bluish-gray	1270	1500
"Gravel", water rose to within 60' of top	60	1560
Shale, bluish gray	200	1760
Dakota Group		
"Nearly all sandstone, soft water at top, hard water below; water rose to within 75' of top of well.	340	2100
"Very hard rock, of which 4 or 5 feet were exceedingly hard."	30 or 40	2230
Shale, bluish gray, like that above, with showing of heavy, dark oil. The water from the sand at 1760 to 2100 was not cased off, and the showing of oil came up through the water	130	2260

WHITEHORSE WELL

Location: S.E.¼, T. 15 N., R. 26 E., Dewey County.
Drilled: Norbeck Company, 1934.
Source: Harold Norbeck
Elevation: 1720 feet

	Thickness	Depth
Pleistocene		
Clay	21	21
Gravel	5	26
Pierre, Niobrara, Carlile		
Shale	1446	1472
Greenhorn		
Lime rock with streaks of shale	67	1539
Graneros		
Shale	278	1817
Shale, sandy	40	1857
Shale	2	1859
Dakota Group		
Shale with streaks of sand	121	1980
Sand with streaks of shale	21	2001
Sand	7	2008
Sand	13	2021

STANDING BUTTE WELL

Location: Sec. 9, T. 7 N., R. 27 E., Stanley County.
Drilled: South Dakota Development and Refining Company
Source: Information furnished by the company.
Elevation: 1958.1 feet

	Thickness	Depth
Pierre (and younger)		
"Pierre" shale	927	927
Niobrara (?)		
Shale rock, gray	6	933
Shale, gray, sandy, carrying dry gas	30	963
Carlile		
Shale	437	1400
Greenhorn		
Sand and water	50	1450
Graneros		
Shale	285	1735
Dakota		
"Dakota" sandstone carrying water with gas and oil showing	170	1905
Fuson		
"Fuson" shale	35	1940
Lakota		
"Lakota" stone	36	1976
Morrison		
"Morrison" shale	214	2190
Morrison or Sundance		
"Base of the Morrison or upper Sundance"	80	2270
Sundance		
Lime rock, penetrating lower sandstone	9	2279

	Thickness	Depth
Water sand	11	2290
Lime rock	2	2292
Pyrites, iron, shell	2	2294
Sand, loose white	13	2307
Shale, gray	18	2325
Water sand, with great water flow	25	2350
Coal	6	2356
Sandstone	26	2382
White sand	3	2385
Sandstone	7	2392
Fuller's earth	10	2402
Sandstone	3	2405
Clay	7	2412
Spearfish		
Redbeds carrying streaks of gypsum and sand	147	2559
Minnekahta		
Oil sand	1	2560
Red bed	4	2564
Tar sands carrying oil	6	2570
Opeche		
Red beds	45	2615
Minnelusa		
Sand showing tar	5	2620
Sand, black	5	2625
Sandrock, hard, showing gas and tar	32	2657
Shale, black flakey	2	2659
Gypsum	1	2660
Broken fragments of sand and shale, more gas	5	2665
Broken formation, some gypsum	5	2670
Sand rock	10	2680
Broken formation	5	2685
Shale, gray, tough	42	2727
Pink formation showing lime	3	2730
Pink rock	25	2755
Limestone shells, conglomerate between	9	2764
Pink sticky formation	7	2771
Conglomerate	10	2781
Shale, gray	6	2787
Conglomerate	11	2798
Conglomerate, gas showing	32	2830
Broken formation, gypsum and lime	10	2840
Lime and gypsum	8	2848
Shale, red	25	2873
Shale, black	4	2877
Shale, red	3	2880
Lime, gypsum, black shale	30	2910
Clay, yellow tough	10	2920
Shale, red	10	2930
Sandstone, hard, shell	5	2935
Sand, small flow of water	5	2940
Sand, very sharp	27	2967
Shale, light, sandy	23	2990
Shale, gray, sandy	20	3010
Sandy, heavy water flow	17	3027

	Thickness	Depth
Pahasapa		
Lime, white, medium hard----------------	63	3090
Lime, very hard-------------------------	70	3160
Lime, medium hard-----------------------	10	3170
Lime with hard, medium and soft layers--	338	3508

SCHOOL LANDS NO. 1 (ZEAL) WELL.

Location: SE$\frac{1}{4}$, N.W.$\frac{1}{4}$ Sec. 16, T.9 N., R. 17 W., Meade County.
Drilled: Cosden Oil Company, 1927.
Source: Cosden Oil Company. Correlation by Mrs. E.R. Applin, in Journal of Paleontology, Vol. 7, pp. 215-217, 1933.
Elevation: 2177.8 feet

Recent, Quaternary, Tertiary and Fox Hills (?)		
Shale, brown---------------------------	50	50
Shale, dark----------------------------	50	100
Shale, light---------------------------	17	117
Shale, dark----------------------------	28	145
Shale, brown---------------------------	295	440
Pierre		
Shale, brown---------------------------	424	864
Shale, blue----------------------------	226	1090
Shale, gray----------------------------	108	1198
Niobrara		
Shale, gray----------------------------	42	1240
Shale, light gray----------------------	50	1290
Shale, gray----------------------------	155	1445
Shale, brown---------------------------	275	1720
Carlile		
Shale, brown---------------------------	265	1985
Shale, brown with a little sand--------	30	2015
Greenhorn		
Shale, brown with a little sand--------	32	2047
Lime shell-----------------------------	13	2060
Shale, black---------------------------	15	2075
Lime shell-----------------------------	2	2077
Shale, dark gray-----------------------	233	2310
Lime shell-----------------------------	3	2313
Shale, dark gray-----------------------	18	2331
Graneros		
Shale, dark gray and at bottom some sand	213	2544
Dakota		
Water sand; struck water possibly in sand a couple of feet; water raised 300 feet of top-------------------------	7	2551
Sand and lime in formation, mixture formation------------------------------	14	2565
Gray shale at 2566, cemented casing to shut off water----------------------	5	2570

	Thickness	Depth
Shale, gray, or near the "Dakota" sand-	8	2578
Sand, gray	22	2600
Sand, white; "Dakota" sand and artesian flow water, tasted salty, and warm water	72	2672
<u>Fuson</u>		
Shale, blue	80	2752
Shale, black, and just going into a sand, "Lakota"	68	2820
<u>Lakota</u>		
Sand and very hard; very large flow of artesian water; very warm	2	2822
Sand, total thickness 105 ft., called the "Lakota"	103	2925
Shale, gray, and the formation at the bottom was sandy	45	2970

OLE TANBERG NO. 1 (RED ELM) WELL

Location: N.W.$\frac{1}{4}$ Sec. 9, T. 11 N., R. 19 E., Zieback County.
Drilled: Cosden Oil Company, 1928-30.
Source: Paul L. Applin, Chief Geologist. Correlation by Mrs. E. R. Applin.
Elevation: 2327.5 feet
Remarks: Abstract from detailed sample study. For detailed log see Report of Investigations 4 or 26, South Dakota Geological Survey.

No Record	40	40
Fox Hills	240	280
Pierre	1360	1640
Niobrara	200	1840
Carlile	337	2177
Greenhorn	203	2380
Graneros	365	2745
Dakota	20	2765
Fuson	206	2971
Lakota	68	3039
Morrison	181	3220
Sundance	285	3505
Spearfish	76	3581

PRAIRIE OIL AND GAS WELL

Location: Sec.2, T. 140 N., R. 73 W., Kidder County, N. Dak.

Source: Correlation by Dr. Virginia A. Kline, N. Dak. Geol. Sur.
Elevation:
Remarks: Abstract of detailed sample study. Although the well is located nearly 140 miles north-northeast of Cheyenne Agency, the lower part of the section is so strikingly different from the Black Hills, that it is included here for comparison, and because some of the formations may conceivably extend southward into this area.

	Thickness	Depth
Pleistocene		
Drift, clay and gravel	56	56
Cretaceous		
Pierre shale	1634	1790
Niobrara lime and shale	80	1870
Benton shale	475	2345
Dakota sandstone	30	2375
Fuson shale	82	2457
Lakota sandstone and shale	78	2535
Devonian		
Red rock, lime and shale	454	2989
Silurian		
Stonewall lime	151	3140
Ordovician		
Stony Mountain lime and sand	327	3467
Red River shale, lime and sand	138	3605
Winnipeg shale	214	3819
Cambrian ?		
Deadwood ? sand and shale	65	3884