

SOUTH DAKOTA
STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

**

Report of Investigations
No. 29

**

A STRUCTURAL SURVEY
OF THE
PIERRE GAS FIELD, SOUTH DAKOTA

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By
Monta E. Wing

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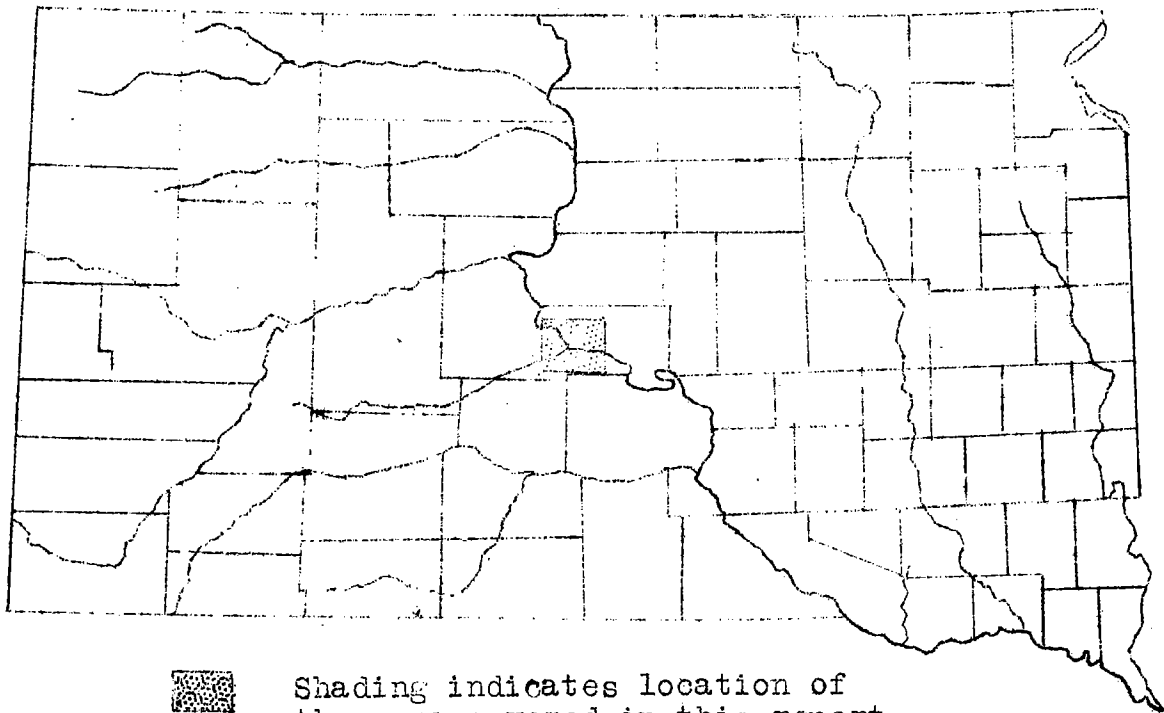
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	Page
FOREWORD - - - - -	1
AREA OF REPORT - - - - -	3
TYPE OF SURVEY - - - - -	3
PURPOSE OF SURVEY - - - - -	4
STRATIGRAPHY - - - - -	9
The Sully Member - - - - -	9
The Agency Shale - - - - -	10
The Oacoma Zone - - - - -	10
The Verendrye Beds - - - - -	11
The Virgin Creek Member - - - - -	12
The Mobridge Member - - - - -	12
SUBSURFACE FORMATIONS - - - - -	13
THE STRUCTURE - - - - -	17
LOCATION AND DEPTH OF TEST WELLS - - - - -	19

INDEX MAP
of South Dakota



Shading indicates location of
the area covered in this report.

A STRUCTURAL SURVEY OF THE PIERRE GAS FIELD, SOUTH DAKOTA

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FOREWORD

The search for oil in a non-producing area is in many cases an evolutionary process. It begins with reconnaissance surveys and is followed by detailed studies of outcropping formations. When sufficient information has been gathered, a study may be made concerning the oil producing possibilities of the State or other large unit area. Finally, the more promising localities are recognized and these are intensively studied and then tested with the drill.

The search for oil in South Dakota has proceeded along these lines. In the early days many geologists made reconnaissance surveys along the Missouri River, while the search for rich ore deposits led others across the plains to the Black Hills. Todd¹ added much to the knowledge of the geology of the state and published many reports, one of the best of which was his first and second biennial reports published in 1898.² In more recent times Freeman Ward, State Geologist from 1915 to 1926 and E. P. Rothrock, State Geologist since 1926 have made many separate studies of the geology of the state. Typical of the more detailed studies concerned with individual formations is the one made by W. V. Searight, of

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1. State Geologist of South Dakota from 1893 to 1908.
 2. Geology of South Dakota, Geological Survey Bulletin No. 2, 1898.

the Pierre Formation which was published in 1937 as Report of Investigations, No. 27 of the South Dakota State Geological Survey.

Much of the geology of South Dakota has been determined in connection with investigations of water supplies. Dr. N. H. Darton published a long series of bulletins between the years 1901 and 1918 in which he described the geology and water resources of the Great Plains region. In the latest report of this character E. P. Rothrock described the geology, and T. R. Robinson, Jr. described the hydrology of central South Dakota. This was published in 1936 as Report of Investigations No. 26 of the South Dakota State Geological Survey.

In the meantime considerable interest had developed in the possibility of oil occurring in the state and in 1920 Roy A. Wilson was given the task of making a general survey of the oil possibilities in South Dakota. In a bulletin¹ published in 1922 Wilson described the geology of petroleum, the geologic features of South Dakota and discussed the possibilities of petroleum occurring within the state. This pointed the way for more detailed investigation of certain promising areas and since that time several investigations have been made and a number of deep wells drilled.

The present investigation may be classed as one concerned primarily with a promising though limited area.

1. R. A. Wilson, The Possibilities of Oil in South Dakota, South Dakota State Geological Survey, Bulletin 10, 1922.

AREA OF REPORT

The area concerned in this report centers at Pierre and covers a considerable portion of Stanley and Hughes counties. An examination of the accompanying map will show that the survey extended north from Pierre along both sides of the Missouri River to Oahe, south to the Stanley County line including the Antelope Creek section, and southwest along Bad River to the station of Teton on the Chicago, Milwaukee, St. Paul and Pacific Railroad including an area of more than two hundred square miles.

As will be explained in the description of the geology, the survey was necessarily limited to the bluffs along the Missouri and Bad Rivers and their tributaries. The flood plains of the rivers are underlain with alluvial deposits completely hiding the structure of the underlying bed rock. Some of the upland areas are extremely flat and contain no cuts in which the structure of the underlying formations could be ascertained. Nevertheless, the survey was sufficiently extensive to show the principal structural features of the area.

TYPE OF SURVEY

The survey consisted of the usual type in which the structure of possible oil or gas bearing strata beneath the surface was sought by examining the structure of outcropping beds or those appearing at the surface. For this purpose, the plane-

table and telescopic alidade were used and elevations were carried from known points--U.S.C. and G.S. and U.S.G.S. bench marks--to many places throughout the area where identifiable horizons appeared. This type of survey is much more accurate than the reconnaissance surveys previously conducted in the area by means of hand levels and altimeters and has the further advantage of permitting the plotting of surface features while the survey is being conducted. This type of survey, also, has preceded the development of many of the major oil fields of the country and was thought to be the next step necessary in the search for oil along the Missouri River in South Dakota.

Two plane-table parties were occupied during the latter part of the summer of 1937 in making the present survey. The first was under the personal direction of the State Geologist with Mr. John A. Trantina as engineer. The writer was geologist for the second party with Mr. Leonard G. Stevens as engineer. The writer was impressed with the interest shown in the survey by the state officials at Pierre and by residents in the area. Credit should be given to almost every rancher living in the area for information given concerning wells, etc. He, therefore, wishes to express his thanks to all of these people for their courtesy and cooperation.

PURPOSE OF SURVEY

The present survey was concerned primarily with determin-

ing the possibilities of obtaining oil in the region adjacent to Pierre. While other surveys have been made in this same general region with a similar purpose in mind, these have been more reconnaissance in nature. Consequently, the present survey does not duplicate the work done by former geologists. It may be stated that these earlier geologists did not report any too favorably on the area but since their reports were made new developments which have occurred seem to justify the present survey.

Some of the reasons for conducting the recent survey in the Pierre area are as follows:

1. Natural gas has been produced in the Pierre field for over thirty years. It is a well known fact that oil and gas often occur together or that they are concentrated underground under the same conditions. Both are transported by water and are trapped under anticlines or other favorable structures. Consequently, the presence of natural gas in the area led to the hope that oil might be found, also.

That the gas in the Pierre field is dry gas and not the type usually associated with oil does not disprove the presence of oil in formations deeper than those in which the gas occurs. As a matter of fact, shows of oil were reported from the Standing Butte well in Sec. 9, T. 7 N., R. 27 E. less than thirty miles from Pierre. At 2559 feet the driller reported a sand containing, "a large quantity of oil". Oil was reported from an artesian well, also, the Ike Geyer well, a few miles west

of the Standing Butte test, (S.E. Sec. 17, T. 7 N., S. 27 E.)

2. Certain structural features of the rocks in the Pierre region called for further investigation. The dominant structural feature of central South Dakota is a northwestward plunging syncline located midway between the Black Hills uplift on the west and Pre-Cambrian quartzites and granites on the east. The Pierre area lies on a broad terrace-like structure on the eastern limb of this syncline. This is somewhat similar to the structure in eastern Kansas and elsewhere where oil has been found. Consequently, it was thought wise to investigate further the details of this structure.

3. One of the purposes of the present survey was to determine the possibilities of further gas production in the area. Although gas has been produced in the state for over forty years, there has been considerable uncertainty regarding the geologic conditions under which it occurs. If the gas is shale gas, as believed by a number of authors, production will probably continue over a great many years, although future wells will probably not be any larger than those drilled in the past. If gas production is dependent on flow of water from artesian wells, then production will be maintained only so long as the wells are kept as flowing wells. If this is the case then gas production will soon be a thing of the past unless steps are taken to control the flow of water from wells which

are now allowed to flow freely thus reducing the pressure which forces the water to the surface. Thus, there may be a two-fold purpose in controlling the artesian wells. They should be preserved for the water which they yield so cheaply and to maintain the gas supply.

If, on the other hand, the gas occurs in definite anticlinal structures, then future supplies might be found by determining the location of other similar structures. Even though the present gas wells are not located in identifiable structures, it is believed that future supplies should be sought by drilling on those structures indicated later in the report.

Natural gas in South Dakota is a very valuable asset, the total production amounting to approximately 10,000,000 cu. ft. per year. If the value were to be determined on the basis of outside fuel which it replaces, the figure would be impressive. Consideration of future supplies at the present time is extremely important.

4. An additional purpose of the survey was to determine whether or not a structural survey could be made on beds in the Pierre shale. This type of survey depends on whether or not there are identifiable horizons in the formation upon which elevations can be determined. Dr. Rothrock, in his preface to Searight's¹ report on the stratigraphy of

1. W. V. Searight, Lithologic Stratigraphy of the Pierre Formation of the Missouri Valley in South Dakota, Report of Investigations No. 27, State Geological Survey, 1937.

the Pierre formation states: "The Pierre formation has long been a stumbling block to geologic progress in South Dakota. Its thickness, known definitely in but few places, is so great that it has been a serious handicap in determining the depth of artesian sands and other formations which might be of value. Outcropping over a third of the western half of the state and immediately underlying the glacial drift in at least two-thirds of the eastern half, it has proven a great drawback to prospecting by making impossible the detection of structural and stratigraphic feature in this great area."

Searight made a careful study of the Pierre formation in the Missouri River valley. His report was an important contribution to the stratigraphy of the state and furnished the tool for the present work. It was found that the Oacoma beds, which Searight described, could be easily recognized and that certain concretionary beds in the Oacoma zone and higher could be definitely identified over most of the area studied. The present survey demonstrated that a structural survey could be conducted where the Pierre formation outcrops.

STRATIGRAPHY

The stratigraphy of the Pierre area is relatively simple. The only bedrock exposed is the Pierre formation of Cretaceous age. Surficial deposits consist of glacial boulders, gravel and loess of Pleistocene age occurring on the hills and slopes north of the Missouri River, and alluvial gravel of Tertiary age on hills and ridges south of the Bad River.

The Pierre is one of the principal subdivisions of the Cretaceous system and consists of a thick body of shale lying between the Niobrara chalk rock below and the Fox Hills sandstone above. Only the Pierre is exposed in the area of this report, however. Of its five subdivisions, only three, the Sully, Virgin Creek, and Moberg members are exposed in the area. The relation of these members to the rest of the formation is shown in the following columnar section taken from Searight's report.¹

The Sully Member

As described by Searight² "the Sully member of the Pierre consists of the body of shale lying between the chalky beds of the upper Gregory and the base of the highly bentonitic beds which lie at the base of the Virgin Creek member."

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1. W. V. Searight, Lithologic Stratigraphy of the Pierre Formation of the Missouri Valley in South Dakota, Report of Investigations No. 27, State Geological Survey, 1937, plate III.
 2. Searight, op. cit., p. 21.

The State Geological Survey recognizes three subdivisions of the Sully member--the Agency, Oacoma, and Verendrye zones. These are distinctly recognizable near Pierre and were most useful in the present survey.

The Agency Shale

The Agency shale is the lowermost subdivision and is exposed just above the flood plain of the Missouri and Bad rivers. Where typically exposed, it consists of a light gray siliceous shale. It is not laminated but is more or less massive. Individual layers have a conchoidal fracture and break into angular chips. In fresh cuts such as in road and railroad cuts and in steep bluffs along the rivers this shale is stained a dark rusty-brown color. This color, however, is found only on the surface and does not extend into the rock except along joints. Large flattish concretions were observed in this zone but seemed not to occur at any distinct horizon. Likewise a number of thin seams of bentonite were observed but it was impossible to determine just how persistent they are.

The Oacoma Zone

The Oacoma zone consists of light gray, flaky shale interbedded with slightly darker bands. It is recognizable in the area of this report because it causes a light band 30 or 36 feet wide between the Agency below and the dark colored Verendrye zone above. Then, too, this zone is marked by less uniform beds and this lack of uniformity causes

benches or stair-step effect along the bluffs and on the sides of characteristically barren knolls.

Manganiferous iron nodules, so characteristic of the Oacoma zone elsewhere are almost totally absent in the Pierre area but there is a moderately prominent layer of large calcareous concretions occurring on top of the third five foot step or within six or eight feet of the top of the zone. These concretions vary from a few inches to several feet in diameter. They are light gray in color inside but are stained a chocolate brown on the exterior and along fractures. Another characteristic feature is that they fracture into thin vertical slices trending in one direction. In several places their exterior was covered with a cone-in-cone layer more than an inch thick.

Since this layer of concretions is the most easily recognized in the area, the accompanying map has been contoured on this horizon.

The Verendrye Beds

The Verendrye zone consists of medium gray shale which weathers to brown and gray gumbo. Moderately fresh exposures of the lower part exhibit to a slight extent the banding and stair-step effect of the Oacoma beds.

Due to numerous layers of black concretions in the upper part and the presence of these on the slopes below, this zone appears much darker from the distance than either the Oacoma or Agency. The concretions are principally black or

dark reddish black in color and are thin. They commonly break into blocks 1-2 inches in diameter.

The Virgin Creek Member

The Virgin Creek was named by Searight from exposures along Virgin Creek in Dewey County. It includes the light grey shales, containing numerous thin layers of bentonite, lying above the Verendrye with its black concretionary layers and below the similar but more highly calcareous shales of the Mobridge. It is divided on the basis of lithology into a lower and an upper zone.

The lower Virgin Creek consists of medium gray shale which weathers into thin purplish flakes with a metallic sheen which distinguishes it from the Verendrye. This zone, however, occurs only near the tops of the hills and is not well exposed.

The total thickness of the Virgin Creek southwest of Fort Pierre is approximately 150 feet.

The Mobridge Member

The Mobridge member consists of highly calcareous shale, marl and chalk beds varying in color from medium to dark gray. The member weathers to buff colored clay beds, being lighter in the lower and upper parts. The only exposure near Pierre or Fort Pierre is in southern Stanley county where it underlies the highest flats.

SUBSURFACE FORMATIONS

Subsurface formations, known to be present, range in age from Mississippian to the unexposed part of the Pierre (Late Cretaceous). It is possible that rocks older than the Mississippian may underlie the region though none that old have been reached with the drill in this part of South Dakota.

About the Black Hills there outcrops a series consisting of alternating beds of sand and green shales of Cambrian age at the base of the sedimentary section. Overlying these are thick limestones of Ordovician and Mississippian age (the Whitewood, Englewood and Pahasapa formations) about 700 feet thick which correspond to the Madison limestone of the Rocky mountains. Above the limestones lie typical Pennsylvanian beds of alternating thin sands, shales, and limestones (the Minnelusa formation). Then comes a very conspicuous series of red beds (the Opeche, Minnekahta, and Spearfish formations) of Permian and Triassic age. Above the red beds lie vari-colored clays and sands, Jurassic in age (the Sundance, Unkpapa, and Morrison formations) and on top of these the heavy sandstones and intervening shales of the Lakota-Fuson-Dakota group which furnishes the artesian water in the Pierre area. These artesian beds are of Cretaceous age and lie from 1200 to 1400 feet below the surface at Pierre.

Above them lies a series of black shales with some limy

shells and dark chalk which is usually mistaken for shale by the driller.

In drilling between the Black Hills and the Pierre area the thick red beds and the heavy limestone have been easily recognized. Between these formations under the plains lie beds of varied thickness which have been traced as far eastward as the Standing Butte well and which should continue, therefore, under the Pierre area.

The character and approximate thickness of the beds which may be encountered in drilling the Pierre area can be inferred from the following well logs:

Log of Pierre City Well No. 3

Location: T. 110 N., R. 79 W. Hughes County, S. Dak.
Drilled by Lewis Greenough in 1910.
Reported to E. C. Perisho in 1910.

Feet	
0 - 300	Soft material, sand, mud, boulder clay, etc.
300 - 350	Upper shale
350 - 650	"Pierre" shale; rubber-like substance which looked like asphaltum, burned with black smoke; odor like asphaltum--25 feet, water greasy.
650 - 960	"Benton" shale.
960 - 1280	"Dakota" sandstone; first flow.
1280 - 1300	Soft sandstone; main flow; large volume of water.

Log of Pierre City Well, 1929

Location: NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 4, T. 110 N., R. 79 W., Hughes County, S. Dak.
Drilled by the Norbeck Company.
Approximate curb elevation: 1440 feet.

Feet	
0 - 60	Silt or yellow sandy clay
60 - 210	Gray shale

Feet		
210 - 850		Dark shale; at 850 ft. a two gal. flow and a little gas.
850 - 1160		Dark to gray shale with scattered streaks of sandstone.
1160 - 1165		Sandstone
1165 - 1310		Unrecorded
1310 - 1316		Good sandstone
1316 - 1341		Gray shale and small layers of sandstone. Perforated from 1159 ft. to 1341 ft.

Log of Standing Butte Well

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

Feet		
<u>Pierre</u>	1 - 927	"Pierre" shale
<u>Niobrara</u> ?	927 - 933	Gray shale rock
	933 - 963	Gray sandy shale carrying dry gas
<u>Carlile</u>	963 - 1400	Shale
<u>Greenhorn</u>	1400 - 1450	Sand and water
<u>Graneros</u>	1450 - 1735	Shale
<u>Dakota</u>	1735 - 1905	"Dakota" sandstone carrying water with gas and oil showing
<u>Fuson</u>	1905 - 1940	"Fuson" shale
<u>Lakota</u>	1940 - 1976	"Lakota" stone
<u>Morrison</u>	1976 - 2190	"Morrison" shale
?	2190 - 2270	Base of the "Morrison" or upper "Sundance"
<u>Sundance</u>	2270 - 2279	Line rock, penetrating lower sandstone
	2279 - 2290	Water sand
	2290 - 2292	Line rock
	2292 - 2294	Pyrites, iron, shell
	2294 - 2307	Loose white sand
	2307 - 2325	Gray shale
	2325 - 2350	Water sand, with great water flow
	2350 - 2356	Coal
	2356 - 2382	Sandstone
	2382 - 2385	White sand
	2385 - 2392	Sandstone
	2392 - 2402	Fuller's earth
	2402 - 2405	Sandstone
	2405 - 2412	Clay
<u>Spearfish</u>	2412 - 2559	Red beds carrying streaks of gypsum and sand

<u>Minnekahta</u> --	2559 - 2560	Oil sand
	2560 - 2564	Red bed
	2564 - 2570	Tar sands carrying oil
<u>Opeche</u> --	2570 - 2615	Red bed
<u>Minnelusa</u> --	2615 - 2620	Sand showing tar
	2620 - 2625	Black sand
	2625 - 2657	Hard sand rock showing gas and tar
	2657 - 2659	Black flaky shale
	2659 - 2660	Gypsum
	2660 - 2665	Broken formation of sand and shale, more gas
	2665 - 2670	Broken formation, some gypsum
	2670 - 2680	Sand rock
	2680 - 2685	Broken formation
	2685 - 2727	Tough gray shale
	2727 - 2730	Pink formation showing lime
	2730 - 2755	Pink rock
	2755 - 2764	Limestone shells, conglomerate between
	2764 - 2771	Pink sticky formation
	2771 - 2781	Conglomerate
	2781 - 2787	Gray shale
	2787 - 2798	Conglomerate
	2798 - 2830	Conglomerate, gas showing
	2830 - 2840	Broken formation, gypsum and lime
	2840 - 2848	Lime and gypsum
	2848 - 2873	Red shale
	2873 - 2877	Black shale
	2877 - 2880	Red shale
	2880 - 2910	Lime, gypsum, black shale
	2910 - 2920	Tough yellow clay
	2920 - 2930	Red shale
	2930 - 2935	Hard sandstone, shell
	2935 - 2940	Sand, small flow water
	2940 - 2967	Sand, very sharp
	2967 - 2990	Light sandy shale
	2990 - 3010	Gray sandy shale
	3010 - 3027	Sandy, heavy water flow
<u>Pahasapa</u> --	3027 - 3090	White lime, medium hard
	3090 - 3160	Lime, very hard
	3160 - 3170	Lime, medium hard
	3170 - 3508	Lime with hard, medium, and soft layers

THE STRUCTURE

As stated previously in this report, the principal structural feature of western South Dakota is the Lemmon syncline or structural trough lying between the Black Hills on the west and the crystalline area in the eastern part of the state. The axis of this great syncline lies beneath Lemmon and extends southeastward through Kadoka. It plunges toward the northwest so that any single formation like the Dakota formation lies at a lower level along the axis of the syncline in that direction.

The major structure of importance in the Pierre area is a broad flat or terrace structure extending in a north-east-southwest direction. The flatness of the formation is shown by the similarity of elevations on the Dakota water bearing sand in the Standing Butte well and in wells at Pierre. At Standing Butte the top of the Dakota lies at an altitude of 223 feet above sea level while at Pierre the same formation lies at approximately 300 feet above sea level or only 78 feet above that of the Standing Butte well. Again, the flatness is shown by elevations determined in the present survey. An examination of the accompanying map will show that the bed on which the elevations were determined lies at an altitude of 1560 feet in such widely scattered areas as Antelope Creek, Teton and Oahe.

This broad terrace structure is considered of very great importance in the accumulation of natural gas in the Pierre

area or in a broad band extending in a direction northeast and southwest of the city. If oil is found in South Dakota, it will probably be found some place along this structure. The structure deserves, therefore, much more study.

The present survey has shown that there are minor anticlinal folds trending mainly northwest-southeast across the major structure. Most of these are small but one in the Antelope Creek area deserves special mention. Its axis lies along a line extending from section 3, T. 109 N., R. 78 W. in Stanley county to section 6, T. 110 N., R. 78 W. in Hughes county. It may be that these two extremities of an apparently single structure are in reality separate. This could not be determined definitely since the structure extends across the Missouri River, and the Oacoma and other bedrock formations on which the survey was based are completely hidden by alluvium. Elevations up to 1590 feet on the Oacoma beds occur near the axis with moderately strong dips occurring on both sides of the folds. The highest point of the fold occurs along the western side of section 19, T. 104 N., R. 33 E. Since no artesian well in the area has been drilled on a structure of this kind, a well drilled here might yield much more gas than any well drilled up to the present time.

Other small folds occur in section 14, T. 4 N., R. 30 E., and in section 3, T. 4 N., R. 31 E. These are not quite as pronounced as the one described above, the highest elevation reached by the Oacoma beds being but little over 1580 feet.

LOCATION AND DEPTH OF TEST WELLS

There is no way of knowing whether the structures appearing on the surface in this area continue to sufficient depth to be important factors in the accumulation of oil or gas in the formations which might carry these products. They offer, however, in the light of the present information, the best site for the location of test wells. It is customary to place the first test as near the top of such a structure as is feasible. One well, however, will not test the region or even one structure, and a test of this country will involve a drilling program which will include sinking a number advantageously placed wells through all sedimentary beds above the Pre-Cambrian.

From the position of the formations in the well at Standing Butte and the local artesian wells it would appear that gas should be struck in the Dakota-Lakota group of sands at about 1200 or 1400 feet. The next possible oil horizon would be in the rocks corresponding to the Minnelusa formation lying just above the big limestone at a depth of about 2400 feet. Shows of oil have been struck in a number of places in the limestone and a complete test should go through them. Judging from the nearness of the quartzite at Mitchell and the relatively small thickness of sedimentary rocks beneath the limestone in the Black Hills it is probable that the base of the possible oil bearing section will be reached at about 4000 feet. As no data is available on the rocks beneath the limestone in

this region, however, a liberal margin of safety should be allowed and the first test should be prepared to go 5000 feet if necessary.

The driller must be prepared to handle artesian flows at a number of horizons; first the Dakota-Lakota sands which may be three or more in number; and second the Sundance sands lying immediately above the red beds. An artesian head was discovered in the limestone in wells farther west. There is no way of telling whether this would prevail in the Pierre area, however. The record at Standing Butte is not clear on this point.

Water for drilling can be impounded in the various streams of the region in sufficient quantities to supply drilling needs for most of the year.

Lastly, it should be kept in mind by promoters and investors alike that this region is unproven territory. Its geology offers formations which may be oil bearing and gas has been produced for many years, but there is no certainty that oil exists even in the most favorable structures.