South Dakota
Geological and Natural History Survey

Freeman Ward, State Geologist

CIRCULAR 27

The Possibilities of Oil in Western Corson County

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EXPLANATION

The Survey issues two series of publications as follows:

BULLETINS.—Some subjects have been investigated a longer time, full data have been gathered, such preparatory or experimental work as was necessary has been entirely or nearly finished. In other words, the study of the subject is actually completed or so nearly so that the results can be relied on and published with a degree of confidence as to their value; and the treatment is full and thorough. In such a case the matter is published as a bulletin.

CIRCULARS.—But often during the progress of the work enough information is at hand to be of value to those interested, yet not enough for a complete treatise. A part of a county or a part of a certain subject may be finished, perhaps, and publication waiting for the complete investigation of the whole county or the whole subject. There may be a demand for statistical matter, or lists of references, or current information, etc., which would hardly do for a formal bulletin. Such partial reports, summary reports, reports of progress, lists, or unit fragments of larger subjects, etc., are handled in circulars.

It is planned to publish the circulars frequently and the bulletins at longer intervals. With this arrangement much information will reach the public with a minimum of delay.

Inquiries may be addressed to the State Geologist, Vermillion, S. D.

INTRODUCTORY

LOCATION

The territory discussed in this circular is located in the western portion of Corson County, and includes all or parts of Townships 18, 19 and 20 N., R 17, 18 and 19 E. It is nearly 150 square miles in area, and is bounded by Grand River, Black Horse Creek, and the Corson County-Perkins County line. The general location is shown in Figure 1.

PURPOSE OF THE WORK

A brief visit to the area in 1924 and a reconnaissance in June, 1925, indicated the presence of sharp, faulted anticlines, and of an area of rocks resembling the Fox Hills and suggesting a large uplift, between Grand River and Black Horse Creek. A detailed examination of the region was therefore undertaken in order to ascertain whether structures large enough to have oil and gas possibilities were present, as well as to throw light on the general structural and stratigraphic problems of the State.

FIELD WORK

In the course of the field work the stratigraphy of the region was examined in detail, the important structural features were

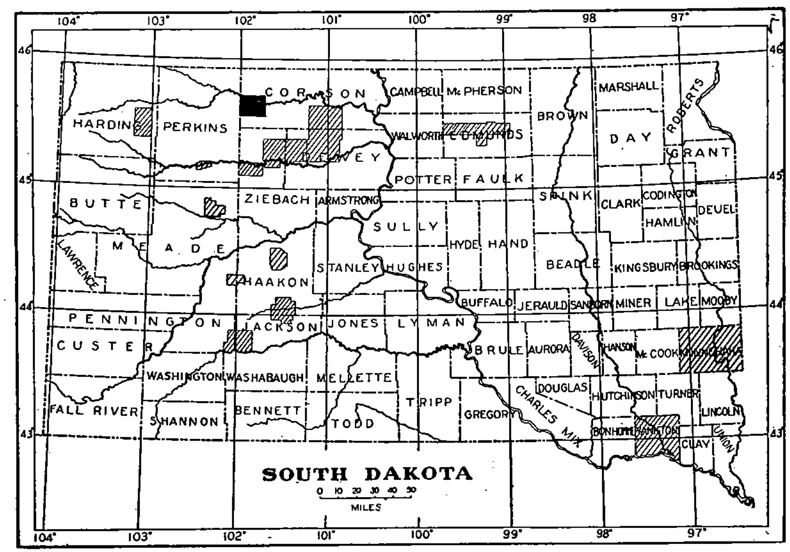

Figure 1. Index Map

Black portion shows area covered by this report.
Shaded portions give location of other reports already published.

mapped with a plane table, and aneroid elevations were obtained on the more distant exposures. About six weeks were spent in the area. A. W. Voorhees operated the plane table and alidade. The elevations shown on the maps are based on two aneroid traverses between the area and the railroad station at Thunder Hawk. These elevations do not agree with those on the reconnaissance topographic map accompanying U. S. G. S. Bull, 575[1], but are in good agreement with those given in U. S. G. S. Bull. 627[2].

TOPOGRAPHY AND FIELD CONDITIONS

The chief topographic features of the area are the Grand River Valley on the north, and the east-west ridge which forms the divide between Black Horse Creek and Grand River. This ridge rises about 450 feet above the level of Grand River to the north; and Black Horse Butte, the most conspicuous landmark in the region, rises nearly 150 feet higher. North of this divide the surface falls off abruptly, and there are many bare cliffs and badlands. To the south, on the other hand, a gently-sloping grassy prairie with few rock exposures stretches toward Black Horse Creek.

A graded dirt road runs from Athboy north to the bridge over Grand River near the northeast corner of section 17, T. 20 N., R. 18 E., and thence to Thunder Hawk, the nearest railroad station, which is about twenty miles distant. Hauling along this road is fairly easy in dry weather, but would be difficult in the rugged badlands in which the structures are found. However, the largest structure is supposed to be close to the road.

Water for drilling might be obtained in certain seasons of the year from the small streams that flow north through the badlands toward Grand River, but as these are apt to dry up during the fall it might be necessary to drill a shallow well or to pipe the water from Grand River or Cottonwood Creek.

STRATIGRAPHY

EXPOSED ROCKS

With the exception of the gravels and alluvium the exposed rocks of the area all belong to the Lance Formation and to a formation which has some of the characteristics of both the Lance and the Fox Hills Transition. (See Figure 2.) In spite of the fact that there are many exposures in the badland areas and along the cliffs, the details of the stratigraphy are highly uncertain. This is owing to the lenticular and variable character of all the exposed formations, and to the fact that no horizon may be traced for any distance. Even where the exposures are perfectly continuous for several miles,

[1]Calvert and others, The Geology of the Standing Rock and Cheyenne River Indian Reservations, North and South Dakota: U.S.G.S., Bull. 575, 1914.

[2]Dean C. Winchester, C. J. Hares, E. Russell Lloyd, and E. M. Parks, The Lignite Field of Northwestern South Dakota: U.S.G.S., Bull. 627, p. 11, 1920.

as along the high cliffs called "The Wall" in sections 30, 31, 32, T. 20 N., R. 19 E., and section 36, T. 20 N., R. 18 E., it is a difficult matter to trace the same horizon continuously. In walking along the same bed it is found that its character and the character of the whole section above and below it changes completely several times. Lenses of sandstone, 60 feet or more in thickness, appear and disappear, and sandstones and shales of the various types, white clays and black carbonaceous clays and thin coal beds may all be observed to terminate within short distances.

Such conditions are, however, typical of the Lance Formation throughout the State. The interesting thing about the formations in this region is that, in spite of the rapid changes in character and thickness, there is a certain order in the sequence of some of the more general characteristics, and that this may be used to divide the strata into several poorly defined members. Unfortunately, however, the characteristics of these members are so vague and variable that they can only be recognized where there are extensive exposures, and even there their identification is a matter of some uncertainty. The results of the effort to classify the exposed rocks of the area is shown in Table 1.

TABLE OF FORMATIONS IN WESTERN CORSON COUNTY

Top
An imperfectly exposed interval consisting of yellowish sandstone with hard brown ledges. Thickness, 50 feet.
One or more beds of medium coarse, bright yellowish brown sandstone with hard brown projecting ledges, forming low buttes; one or more beds of black carbonaceous shale or thin coal at base of the sandstones; may be base of Ludlow Lignitic Member. Thickness, 50 feet.
Somber Shale Member: 50 feet of dark, carbonaceous shale with more or less light brown, yellowish or grayish shale, below which are 50 to 100 feet of yellowish brown sandstone interbedded with brown carbonaceous shale and a subordinate amount of light brown, yellowish or grayish shale.
Pale Clay Member: Pale gray, greenish-gray, and pinkish-gray clays and shales, with a subordinate amount of light and dark carbonaceous shale; lenses of gray and brown sandstone; a few beds of very white shaly sandstone or sandy shale and one or more thin seams of coal or black coaly shale at base; occasional rude banding. Thickness, 0-100 feet.
Basal Sandy Member: Grayish-white sandstone with occasional round brown sandstone concretions, interbedded with a subordinate amount of light gray, greenish-gray or pinkish shale, with several thin beds of black shale or coal and in places one or more thin layers of very white shaly sandstone or sandy shale near base; sandstones and shales frequently show rather faint or imperfect banding. Thickness, 20-100 efet.
Fox Hills-Lance Transition Beds: Gray sandstone, with round brown sandstone concretions and marked banding, interbedded with subordinate amounts of gray, greenish-gray and brown, rarely pinkish, shales and thin beds of black coaly shale. Exposed thickness, 50 to 75 feet.
Base

Table 1

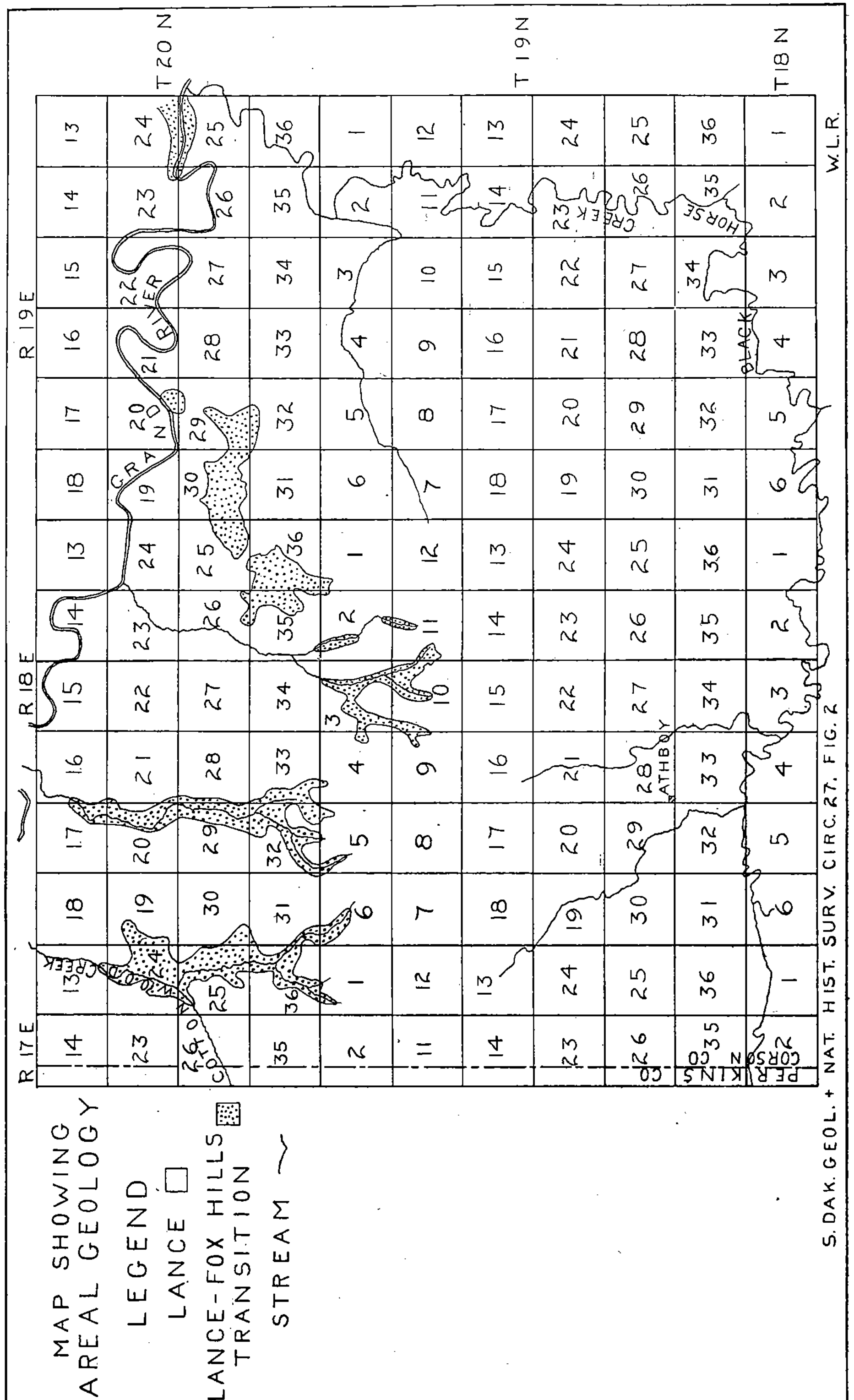

Figure 2

The most important feature of the rocks of the area is the gradual change from rocks resembling the Fox Hills in some respects, to typical Lance. The basal member of the section, called the Lance-Fox Hills Transition Beds, is the most definite of all, except possibly the yellow sandstones and coal beds at the top. The Lance-Fox Hills Transition Beds resemble the Fox Hills in their alternation of bands of grayish shale and sandstone, and in the presence of massive, fine, light gray sandstones with rounded brown sandstone concretions. These are features which are characteristic of the Fox Hills to the south and southeast. On the other hand, the features which resemble the Lance are the frequent intercalations of brown and black carbonaceous shale, thin coals, and light gray or greenish gray shales, and also the absence of marine fossils. While certain exposures of this member look almost exactly like the Fox Hills, its general appearance is more like the Lance than the Fox Hills.

A careful investigation of the stratigraphy was undertaken to ascertain if any of the members was sufficiently definite and widespread to serve as a key horizon for mapping the structure. It appeared that this problem could best be studied by measuring a number of sections through the strata in question and plotting them beside one another. Figure 3, which shows a series of such sections, gives a good idea of the character of the lower half of the exposed rocks in this area. The gradual change from banded beds at the base to beds without banding above suggests a possible means of mapping the structure. If by the relative frequency and irregularity

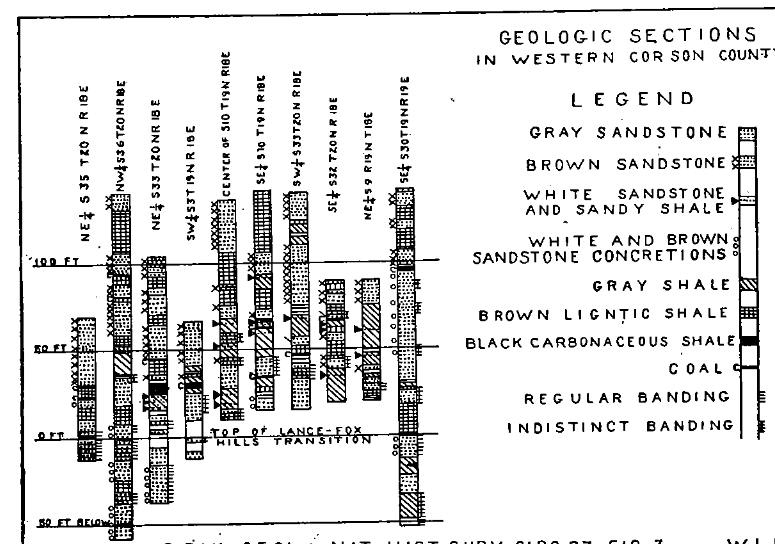

Figure 3. Geologic Sections

of the banding it is possible to estimate the approximate position of a given exposure in the geologic section, a rough idea of the structure could be obtained, even though there were no definite stratum or horizon recognizable. As there is no well-defined upper limit to the Lance-Fox Hills Transition Beds or to the banded beds, it was necessary to take some arbitrary horizon for the purposes of mapping the structure and areal geology. If the horizon were set too high its position would be very uncertain, for the irregularity of the strata, and especially of their banding, increases upwards. On the other hand, if the top of the Lance-Fox Hills Transition Beds were set too low, they would cover such a small area that no general idea could be obtained of the structure. The upper limit was therefore assumed to be at the highest horizon at which there appeared to be a fairly marked difference between them and the Lance above. Owing to the poorly defined character of the member it was probably not possible to estimate its top closer than within fifty feet.

The correlation of the Lance-Fox Hills Transition Beds with the formation of other parts of South Dakota has an important bearing on the regional structural relations of the area. Obviously if the Lance-Fox Hills Transition Beds are equivalent to the Fox Hills to the southeast a large uplift is present. While this problem cannot be settled at the present time, a few facts which have some bearing on it may be cited.

It appears that the sediments of the Fox Hills were derived from the west or northwest. The evidence in other states has been supposed to indicate a westerly source. In Meade County, S. D., Wilson[3] has found that coal beds appear towards the west in typical Fox Hill sandstones. In another area the writer[4] observed that the change in the character of the beds at the base of the Fox Hills or top of the Pierre suggests a source to the west-northwest or northwest. In this area the direction of the cross-bedding of the sandstones in both the Lance-Fox Hills Transition Beds and the Lance strongly supports the idea of a northwesterly or west-northwesterly source. Though the directions of the dips and the oblique laminae are quite scattering, especially in the Lance, nevertheless they are prevailing southeast, or east-southeast.

If the Fox Hills sediments came from the northwest it is obvious that the same horizon, if traced from southeast to northwest, would pass from marine sediments to shore deposits and finally to rocks formed under continental conditions. It is possible, therefore, that the Lance-Fox Hills Transition Beds are really equivalent in time to the true Fox Hills southeast, even though they may belong to the Lance in this area.

In addition to the Cretaceous rocks, deposits of gravel and alluvium occur in the larger valleys and on the terraces or benches along

[3]R. A. Wilson, Oil and Gas Possibilities in Northeastern Meade County: S. D. Geol. and Nat. Hist. Surv., Circ. 23, 1925.
[4]W. L. Russell, Structures in Western Haakon and Eastern Pennington Counties: S. D. Geol. and Nat. Hist. Surv., Circ. 28, 1926.

Grand River. A few scattered gravel pebbles may also be found on the hills several hundred feet above the river. The pebbles in the gravel consist chiefly of sandstones, limestone, chert or flint, with some vein quart, and igneous and metamorphic rocks.

UNEXPOSED ROCKS

Though there is much that is uncertain about the thickness and character of the formations beneath the surface, some idea of them may be obtained from the Black Hills Section, the Standing Butte well northwest of Ft. Pierre, the Irish Creek diamond drill well southwest of Isabel, the wells on the Cedar Creek Anticline in southeastern Montana, the recent rotary-drilled wells at Lemmon and the 1,000 foot well in the S. W. ¼, section 30, T. 20 N., R. 19 E. As, however, the last well was drilled with a jetting rig, no very accurate idea of the formations is obtainable. This well apparently started a few feet below the top of the Lance-Fox Hills Transition Beds, and

THE SUBSURFACE FORMATIONS OF THE AREA

	Name	Thickness in Feet	
Upper Cretaceous	Unexposed Lance-Fox Hills Transition Beds and Fox Hills	150-400	Gray sandstones above with thin bands of sandstone and bluish gray shale below.
			At top 400-700 feet of bluish gray shale with occasional fine, soft, porous sandstones.
	Pierre Shale	1,600	900 feet of light bluish gray shale.
			Dark bluish gray bituminous shale, 150 feet.
	Niobrara	200	More or less calcareous or chalky shale, slightly bituminous and probably containing a few fish scales.
	Carlile Shale	400	Bluish gray shale, possibly containing some sandstones which, if present, are apt to be limy and impervious.
	Greenhorn Limestone	0-50	Thin layers of limestone and shale. May be absent.
	Upper Graneros Shale	500	Bluish gray shale.
	Dakota Sandstones	300	Sandstones interbedded with bluish gray shale which is the equivalent of the Graneros shale farther west, and containing the Newcastle sandstone near the top.
Lower Cretaceous	Fuson, Lakota or Morrison	300	Gray, pink and green shales with some sandstones.
Jurassic	Sundance and Unkpapa	200	Olive-green or reddish shales with possibly some fine white sandstone.
Triassic	Spearfish Red Beds	500	Red sandy shales with gypsum.
Paleozoic		unknown	Shales, limestones and sandstones. Character unknown.

Table 2

reported about 150 feet of sandstone at the top, beneath which were about 550 feet of shales with some sandstones containing oil shows, and nearly 250 feet of shale at the base. The boundary between the Pierre and Fox Hills is quite uncertain in this area, and cannot be determined from the record of the well.

Table 2 gives some idea of the formations which would be encountered in drilling.

The conception of the Dakota sandstone given in Table 2 is based upon the idea that the Dakota sandstone in South Dakota came from the east and that towards the west it gradually gives place to what is called the Graneros shale in the Black Hills. This conception was suggested by the writer in an earlier publication[5] and since then the records of the wells drilled for oil as well as investigations of the exposures made by the writer have tended to confirm it.

A well starting at the top of the Lance-Fox Hills Transition Beds would probably encounter occasional sandstones or sandy zones in the top of the Pierre down to about 700 or 800 feet. A similar but thinner zone of sandstones and sandy shales was found in the Upper Pierre in the Irish Creek oil well[6]. From the character of these sandstones in this well, it may be inferred that in the area under consideration they would be very fine and partly shaly or silty, but of high porosity. They thus offer the possibility of small, very shallow oil and gas production.

The next possible horizons for oil and gas production are the sandstones which may exist in the Carlile shale. In the northeastern Black Hills there are two sandstones in the Carlile shale, but they are too dense and impervious to produce oil and gas, owing to the reduction in porosity by their lime content. If such sandstones are present in this area, and if they are not rendered too impervious by lime, they would be possible horizons for production.

Perhaps the most promising horizon for oil and gas production underlying the area is the Dakota sandstone series, which probably consists of several sandstone strata separated by marine shale. Hence drilling should not be stopped as soon as the first sandstone is penetrated, but should be continued until the pink shales below the marine Dakota have been penetrated.

Sandstones are likely to be encountered in the lower Cretaceous (possibly in part Jurassic) formations equivalent to the Fuson, Lakota and Morrison formations of the Black Hills, but these formations are probably of continental formation in this area, and are not likely to contain enough bituminous material to form oil and gas in commercial quantities. The uppermost sandstones of the group may be sufficiently close to the marine Graneros shales to be of some promise, but the remainder of the sandstones in this group

[5] W. L. Russell, The Possibilities of Oil in Western Ziebach County: S. D. Geol. and Nat. Hist. Surv., Circ. 20, p. 10, 1925.

[6] W. L. Russell. Well Log in Northern Ziebach County: S. D. Geol. and Nat. Hist. Surv., Circ. 18, 1925.

are not likely to be productive unless the oil and gas have reached them through faults or fissures. The Sundance formation is probably in part marine in this area, but it is at present impossible to say whether or not it contains enough bituminous matter to serve as a source rock.

The Paleozoic rocks which probably underlie the Mesozoic formations in this area probably also contain sandstones, but although they must be considered as additional possible horizons for production, not enough is known about them to warrant further discussion.

The depths at which the horizons already mentioned are likely to be encountered are as follows:

Horizon	Depth in Feet
Upper Pierre sandstones	300– 800
Sandstones in Carlile shale	2,300
Dakota sandstones	3,000–3,200
Paleozoic sandstones	4,000–4,500

STRUCTURE

REGIONAL STRUCTURAL RELATIONS

The general structural relations of the area are shown in the may recently compiled by Ward[7]. This indicates that although not on a large regional uplift, it is partly included in an arch of considerable extent. The region under discussion is located in what is generally called the Lemmon Basin, a very shallow synclinal structure of great extent.

METHODS OF MAPPING STRUCTURE

The manner in which the top of the Lance-Fox Hills Transition Beds was used to obtain a general idea of the structure has already been described. The top of this formation is, however, so indefinite that it may be doubted whether the errors produced by attempting to use it in mapping structure are not larger than the genuine folds which may be present. In other words, it is important to decide whether or not the apparent folding is due to the fact that what is apparently the top is not always at the same horizon. An examination of Figure 3 will show how difficult it is to decide where the top of the Lance-Fox Hills Transition Beds should be placed.

For these reasons, it is very desirable to check this method as far as possible by the use of other methods. It is not possible to form any adequate idea of the larger folds in the region by taking local dip readings with a clinometer, for these dips were found to be so exceedingly variable that a map based entirely on them would be very confusing. Moreover, the dips of the larger folds are undoubtedly too low to be mapped in a satisfactory manner by this method. There are, it is true, several small, sharp folds, with dips

[7] Freeman Ward, The Structure of Western South Dakota: S. D. Geol. and Nat. Hist. Surv., Circ. 25, 1925.

as high as six degrees, but even these could not be accurately mapped by local dip readings, for this method would not afford any means of determining the effect of faulting.

It was found that, although there was no bed which could be recognized over the whole area, in a number of places definite horizons could be traced in the badland areas for distances of a mile or two. Elevations taken on these horizons indicate that, in general, their dips conform to the dips of the supposed top of the Lance-Fox Hills Transition Beds. This is to say, their dips are more away from the top of the large fold suggested by taking elevations on this horizon than they are towards it. Structure contours based on elevations taken on such beds are shown on the structure map, Figure 4, as solid lines, and those based on the top of the Lance-Fox Hills Transition Beds alone are shown by broken lines, though of course the position of the top of the Lance-Fox Hills Transition Beds, on which the structure contours are drawn, is not known more accurately in the former areas than elsewhere.

As the Lance-Fox Hills Transition Beds are believed to lie below the true Lance, it is important to know the elevations of the lowest Lance exposures in the streams and lowlands surrounding the structure, for if these exposures are everywhere lower than the Lance-Fox Hills Transition Beds on the top of the fold, a large closed uplift would be indicated. The aneroid elevations obtained on the lowest Lance exposures along Grand River and Black Horse Creek are shown in Figure 4.

STRUCTURAL TYPES AND DETAILS

The chief structural feature of the area, if the elevations on the top of the Lance-Fox Hills Transition Beds may be trusted, is the anticline extending for about five miles northwest of Black Horse Butte, along or just north of the crest of the ridge which extends west from Black Horse Butte. The dip to the north, between the top of the fold and Grand River, or Black Horse Creek apparently amounts to 150 feet or more to the north, 200 feet or more to the northeast, 250 feet or more to the east, and 100 feet to the south. It is not possible to determine the amount of dip to the south, for, although the exposures in that direction are all Lance, the lowest of them is at approximately the same elevation as the top of the Lance-Fox Hills Transition Beds on the top of the fold.

The general distribution of the higher members of the Lance, as shown in the geologic map of Perkins County, indicates that the main fold is probably closed to the west.

Superimposed on this large anticlinal area, as well as on its flanks to the north, are several smaller folds, varying in width from about half a mile to about two miles. The dips of these folds very from less than one degree to six degrees. Folds of this type are found in sections 31, 32 and 33, T. 20 N., R. 18 E.; section 5, T. 19 N., R. 18 E.; section 11, T. 19 N., R. 18 E.; section 1, T. 19 N.,

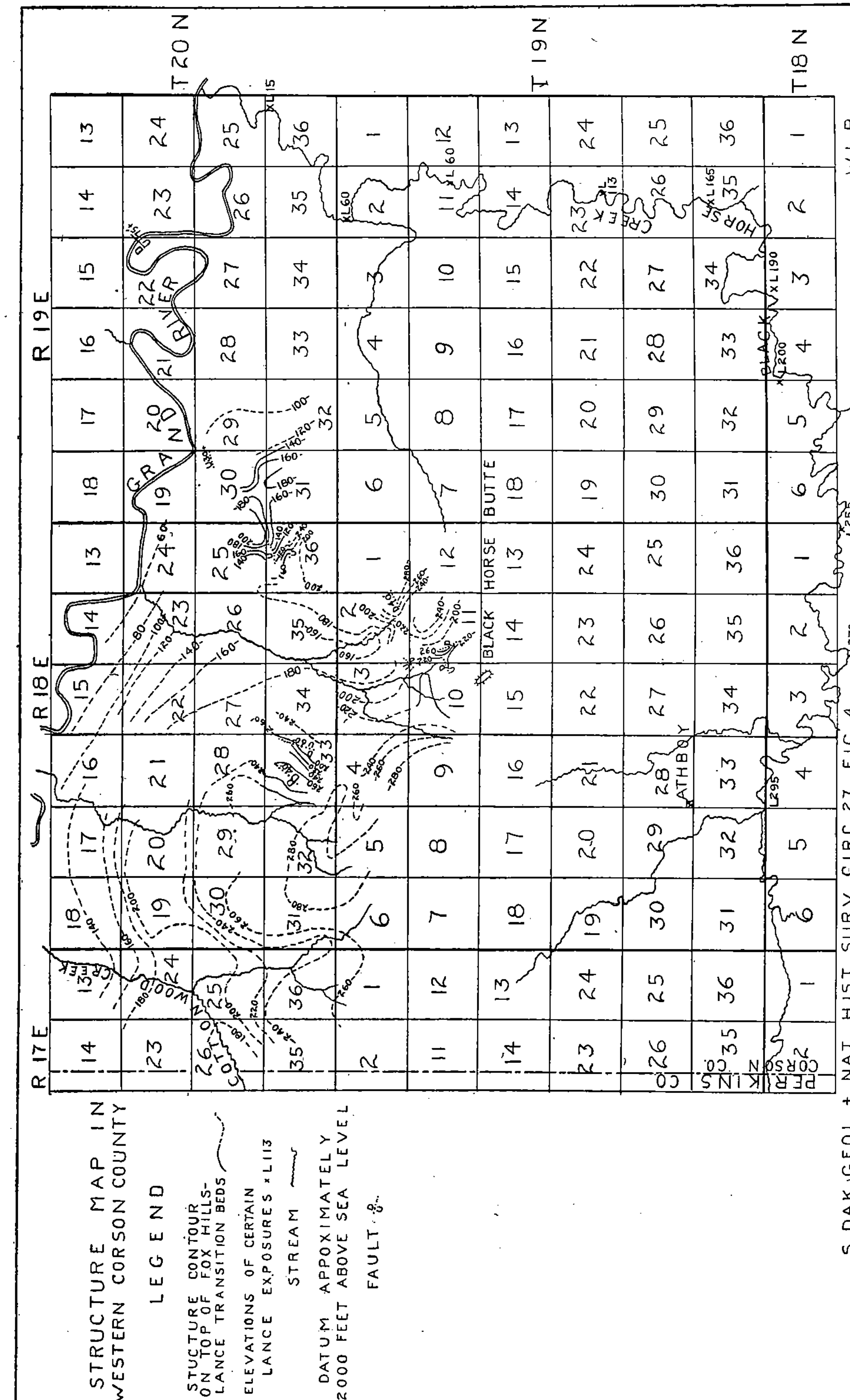

Figure 4

R. 18 E.; and sections 36, T. 20 N., R. 18 E., and 31, T. 20 N., R. 19 E.

The steeper ones of these anticlines are cut by numerous faults, which drop the strata down on the side towards the axis of the anticline. The faults usually trend roughly parallel to the anticlines, and usually dip towards the anticlinal axis at angles of 50 and 70 degrees. There are a number of faults in the area which are not definitely related to any anticline, but all of them are normal faults. The throws of the largest faults actually measured, those in section 36, T. 20 N., R. 18 E., and section 22, T. 20 N., R. 19 E., are about 100 feet, but as there are a great many faults the throw of which cannot be determined, it is possible that some of them are still larger. The throw of the faults varies rapidly from place to place, and none of them may be traced more than half a mile. A few of them exhibit the peculiar bending of the strata along the fault in the direction opposite to the true drag. For a discussion of the origin of the faulting and reversed drag, as well as the methods by which the various structural features may be distinguished from slumps, the reader is referred to the circular describing western Ziebach County (see footnote 5). Figure 5 shows a north-south section through the anticline in sections 25 and 36, T. 20 N., R. 18 E. It is typical of the sharp, faulted anticlines of the area, and brings out clearly the relation of the faults to the axis, and the apparent collapse of the crest. The origin of these structures through tension and the possibility of their growing larger with depth are discussed in full in the circular just mentioned.

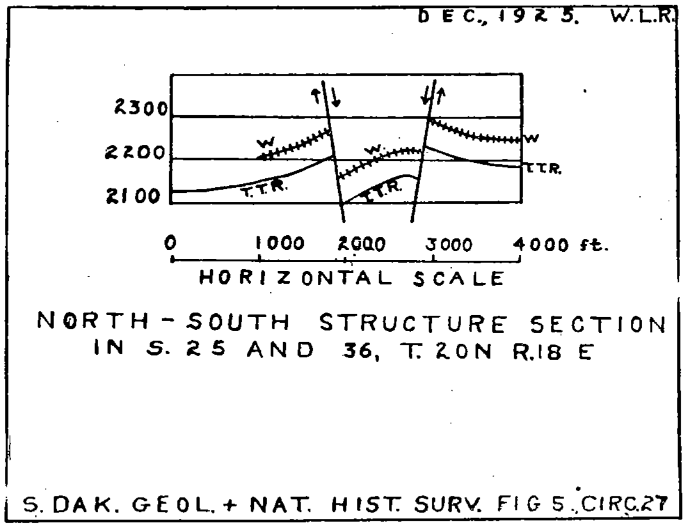

Figure 5

RELATION BETWEEN STRUCTURE AND TOPOGRAPHY

This area resembled the other parts of the plains of Western South Dakota in that there is some relation between the main folds and the topography. Cottonwood Creek and its southeast branch both run in synclines. The main fold is located fairly close to the extensive ridge extending west from Black Horse Butte, and as far as could be ascertained the strata dip away from this elevation in the same general direction as the surface. A number of explanations may be suggested for this relationship, one of the most plausible of which is that it is due to erosion along the contact between the top of the Cretaceous and the base of the White River. From observations elsewhere it may be concluded that the basal member of the White River Formation in this area consisted of soft clays which are readily eroded. If the folding took place after the deposition of the White River, but before its removal, the forces of erosion might strip this covering of clays from the underlying Cretaceous, with such rapidity that elevations and depressions in the base of the clay would become ridges and valleys.

SUMMARY OF EVIDENCE CONCERNING PRESENCE OF LARGE FOLD

As there is so much that is uncertain about the reliability of the key horizon, it may be well to summarize the evidence for and against the presence of a large fold. This uncertainty does not cast doubts on the existence of the smaller, sharper folds. Several horizons may be traced completely across these folds, and the steepness of the dip and its uniformity in the different strata indicate that it is not due to any stratigraphic cause. The evidence in favor of the existence of the large fold may be summarized as follows:

1. Lance-Fox Hills Transition Beds, on which the evidence for the presence of the large fold is based, nearly everywhere lie beneath the typical Lance. That is shown not only by the sections, but by their distribution along the streams, as shown in Figure 2.

2. The top of this formation rises gradually but fairly steadily towards the top of the main fold.

3. Local dips, determined by taking elevations on definite strata which could be traced continuously for distances varying from a few hundred feet to over a mile, are more away from the axis of the major fold than towards it.

4. The relation between the structure and topography is similar to that determined in other areas where the key beds were reliable.

On the other hand, the evidence against the presence of a structure may be summarized as follows:

1. The top of the Lance-Fox Hills Transition Beds is admittedly very uncertain, and in places thick sections of the strata at that horizon may be observed to change from rocks resembling the Lance to typical transition beds.

2. At the northeast corner of the badland area known as the Wall, in section 30, T. 20 N., R. 19 E., fairly thick beds of gray clay and carbonaceous shale appear in the Lance-Fox Hills Transition Beds, and a fault which would be expected to bring up the transition beds instead brings up typical Lance strata. This suggests that the Lance-Fox Hills Transition beds are changing to Lance in this locality. It is, however, the only place at which there are such indications.

It appears to the writer that the arguments in favor of a structure are more convincing than those against it. Nevertheless there is a real possibility that the supposed structures are due chiefly to variations in the stratigraphic position of the top of the Lance-Fox Hills Transition Beds. Consequently before drilling a deep test it would be advisable to put down a shallow diamond drill hole on the top of the structure, preferably near the center of section 32, T. 20 N., R. 18 E. Another shallow test, which should be located along Black Horse Creek south of Athboy, would be desirable to determine the closure of the structure. If the results of these tests are satisfactory, the structure would be worth testing to the base of the Dakota sandstones, for it would then be the largest in this part of South Dakota.

DRILLING PROBLEMS

Although of the cable-tool, rotary and diamond drill systems of drilling each possesses distinct advantages, it appears that the best one to use in an area like this, in which the formations are largely unknown, would be the diamond drill. A very accurate log would be necessary to identify the various horizons and determine when the objective had been reached, and the continuous core obtained by a diamond drill would probably be cheaper. Drillers should be prepared to cope with cavy shales in the Upper Cretaceous rocks, and large flows of water in the Dakota sandstones, the Lower Cretaceous sandstones, and possibly also the Unkpapa sandstone.

OIL POSSIBILITIES

It is generally conceded that, in order to be promising for oil and gas production, an area must be underlain at suitable depths by porous strata associated with bituminous rocks from which the oil could form, and that an anticline or another type of trap must be present to cause the accumulation of the oil. It is likely that some bituminous strata are present at about the horizon of the Dakota sandstone and also in the Carlile shale. Such material may be associated with the Paleozoic sandstones also, but the great depth of these formations makes them less attractive than the Dakota.

One feature of western South Dakota which has seemed unfavorable for oil production is the presence of fresh water in some of the possible horizons, and the supposed artesian circulation. It has

been generally recognized that fresh water is not commonly associated with oil, presumably because of the chemical effect of the substances dissolved in the water, or because of the solution of the gas and lighter constituents of the oil. The artesian circulation, which is sometimes active in sandstones containing fresh water, may also interfere with the formation of the oil pools.

So little is known, however, about the water content of the Cretaceous rocks of northwestern South Dakota, that the assumption that the sandstones would all contain fresh water is unwarranted. In fact a consideration of the known facts, such as the waters encountered in surrounding regions, the origin of the sandstones, and the influence of artesian circulation, suggest that, if any water is found in the Pierre or Carlile in this area, it is apt to be salt or brackish, and that the water in the Dakota sandstones will be slightly salty. The waters in the Lower Cretaceous sandstones are apt to contain sulphates and substances other than chlorides which will give them a "hard" or bitter taste.

For a number of reasons it may be supposed that the artesian circulation in this part of South Dakota is either weak or wanting. An examination made in the field by the writer shows that the Dakota sandstones and Lower Cretaceous sandstones are composed of lenticular sheets rather than continuous layers, as had been previously supposed. The occurrence of slightly salty water in the Dakota sandstones in wells drilled near the Missouri River also suggests that any artesian circulation which may exist passes chiefly farther south. It is likely, therefore, that the currents due to artesian circulation, if they exist at all, pursue a rather tortuous course from one sandstone lens to another, and that certain of the lenses may be wholly unaffected by them.

It will appear from the foregoing considerations that if the results of the shallow testing with a diamond drill are encouraging, the structure would be worth a test to the base of the Dakota at least. While the conditions are not entirely favorable, the chances of obtaining production would be reasonably good. It should be borne in mind, however, that only about one out of three of the best structures are said to be productive, and the chances become still less in areas far removed from production.

CONCLUSIONS AND RECOMMENDATIONS

1. In the region under discussion several rather small, steep, faulted anticlines are present, which have apparently collapsed, owing to the tension.

2. A careful investigation of the structure and stratigraphy reveals that a large anticline is probably, though not certainly, present.

3. Because of the uncertainty of the stratigraphy, and also because of the lack of exposures to the south it would be advisable to

test the structure with two shallow diamond drill holes before drilling a deep test.

4. If the shallow diamond drill holes indicate a large closed fold, it would be advisable to test it to the base of the Dakota sandstone at least.