South Dakota
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Freeman Ward, State Geologist

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Oil and Gas Prospects in Southern Perkins County

By

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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.

SOME GENERAL FACTORS IN OIL ACCUMULATION AS APPLIED TO SOUTH DAKOTA

Many geologists look unfavorably on South Dakota as the possible site of oil fields. This is partly because the exact geologic conditions have not yet been determined, partly because of disagreement concerning the interpretation of the geological data already collected, and partly because there has been no production from the few holes thus far put down. In regard to the latter point, it should be remembered that no dome or anticline at a distance of fifty miles or more from the Black Hills has yet been tested to adequate depth to give definite proof. It is quite obvious, therefore, that the question of oil in the State is not settled, and that further attention could profitably be given to some general conditions which may have an important bearing on the matter.

Some of the lines of evidence which have been the subject of a preliminary investigation are outlined below. When parts of this work have reached a sufficient stage of advancement, further information on the results will be published.

Carbon Ratios.—The geologist has found that a certain amount of deformation is necessary to cause the formation and accumulation of oil in commercial amounts. Also, if the disturbance of the surface rocks of the earth has exceeded certain limits, oil which might have accumulated would be dissipated and lost. In 1915 White[1] proposed the idea that the effectiveness of the changes in the rocks in causing the accumulation of oil, and in destroying it might be inferred from the character of nearby coal. Since this theory was first announced it has been successfully applied to oil conditions in Oklahoma, Texas, and the Appalachian fields by several geologists. Also, no strong objections to it have yet been raised.

The escape of gaseous matter from coals is taken as the measure of the effects of deformation. In the analysis of coals, this may be expressed by taking the "carbon ratio," which is $\frac{\text{fixed carbon}}{\text{vol. matter} + \text{fixed carbon}}$ as given in the proximate analysis. Experience has shown that if this ratio is over 60 per cent or under 50 per cent conditions are not distinctly favorable, and that regions giving ratios from 50 to 55 per cent are the most favorable. It is believed that careful work along this line in South Dakota will do much toward pointing out the areas which offer the best chances of finding oil in paying quantities.

[1]White, David, Some Relations in Origin Between Coal and Petroleum: Wash. Acad. Sci. Jour., vol. 6 (1915), pp. 189-212.

At the present time a number of coal analyses for the State and adjacent areas have been investigated. In the near future more data will be compiled and a definite report made. A preliminary statement can be made now that the carbon ratios found range from 46 to 58. This range leads to the conclusion that general conditions appear to be favorable in parts of the State.

Fault Structures.—The consideration which has been given to faulting as a factor in oil accumulation in South Dakota in the reports of the State Geological Survey has been mainly of a negative character. Such statements as the following have characterized the consideration of faults in the past: "A number of small faults were observed, but in no case are the faults of sufficient magnitude to interfere with the oil possibilities."[1] Further consideration would show that in addition to the point of view formerly taken, there is good reason to consider faults as a possible cause of the accumulation of oil. Many of the more recent discoveries of oil fields have been made in localities where the effects of faulting were the most important thing. The Mexia field in Texas and the more recent discoveries in the western extension of the Cat Creek field in Montana represent accumulations due most largely to faulting. One of the nearest fields in Wyoming, the Osage field,[2] gets its production from fault structure. Altogether, both experience in a neighboring field and the opinion of the majority of oil geologists as expressed in professional publications indicate that faulting should be closely watched for and that faulted domes or anticlines under most conditions should be given preference over those which are not so disturbed. In the future, the effect of faulting will undoubtedly be considered from this viewpoint.

Oil Accumulation in Small Domes.—The accumulation of oil in small domes of the kind characteristic of the plains area of western South Dakota has been considered possible by the State Geological Survey, as is stated in practically all of its publications bearing on oil possibilities. Although the policy of the State Survey has not been to condemn the area because of the slight folding, most geologists in commercial practice seem to have hesitated in recommending tests in the region.

More recently there seems to be even better cause for considering these small folds favorably, at least in certain localities. The recent enlargement of the hydraulic theory of oil accumulation[3] and the prominent example of the effect of water circulation as independent of steep dips which has been found in the Sweet Grass arch oil fields in Montana suggest that low dip structures in South Dakota

[1]Circular 13, p. 9, South Dakota Geological and Natural History Survey: R. A. Wilson and Freeman Ward, 1923.

[2]Collier, A. J., The Osage Field, Weston County, Wyoming: U. S. Geological Survey Bull. 736-D (1922), pp. 95-6.

[3]Further Notes on the Hydraulic Theory of Oil Accumulation: John L. Rich, Bull. A. A. P. G., vol. 7 (1923), pp. 213-226.

deserve further consideration. Rich considers the estimated flow[1] of water in the Dakota sandstone as being rapid for the purposes of oil accumulations. Heald[2] points out that the position held by hydraulic engineers is that the circulation of water is much more active around the edge of a structural basin and relatively feeble in the inner portions.

The application of these theories to the situation in South Dakota is somewhat as follows: Although the circulation of the ground water in the Dakota sandstone may be so rapid in some parts of the State as to prevent the accumulation of oil, in certain others, namely, in the synclinal basin in Perkins County, and the northwestern part of the State generally, it is entirely possible that the movement is slow enough so that small folds might be capable of causing the accumulation of oil. Likewise, it is to be expected that a more unusual disturbance is required to interrupt the circulation of ground water enough to cause oil accumulation near the Black Hills than at some distance where the action would not be so vigorous.

It is also plain that a more irregular sandstone would be likely to have a slower circulation of water under any given structural conditions, and that in the case of a fine sandstone, as compared with a coarse one, the circulation would be slower. Therefore, it is to be expected that the water conditions would be more favorable for oil accumulations in some of the irregular sandstones than in the Dakota sandstone. The favorable consideration given in other parts of this paper to the possible sands in the Benton and to the older formations which occur below the Dakota in the Black Hills is based on this idea.

As has been suggested, a combination of folding with faulting may be the best structural arrangement that can be found in the State, for this arrangement would offer the greatest resistance to water circulation and at the same time would provide the best opportunity for the accumulation of oil and gas. It should also be remembered that more pronounced structures are necessary to cause oil accumulation near the Black Hills uplift than at some distance.

Possibility of More Sandstones Than Formerly Considered.—The point that the character and thickness of the various formations to be found in western South Dakota are known only in a general way in the region some distance from the Black Hills has been made in most of the publications of the State Geological Survey which deal with the question of oil. Important information on this point will be added to our present knowledge by the examination of the well being drilled at Isabel by the Irish Creek Oil Company. A diamond drill is being used there, so that a good sample of all of the rocks gone through is brought to the surface. It is expected

[1]Estimated at 2 feet a year, or less, by N. H. Darton: Eighteenth Annual Report, U. S. Geol. Survey, part IV (1897), p. 609.

[2]K. C. Heald, Discussion of Mr. Rich's paper. Bull. A. A. P. G., vol. 7 (1923), p. 225.

that at least a preliminary examination of the core for a depth of 1,500 feet will be made this winter.

A study of the conditions existing in the State at the time of deposition of the underlying rocks should bring out facts which would make it possible to predict variations in character and to locate regions which deserve more special attention. This work is being continued in the office by an examination of well records. Field work bearing on this question could be profitably undertaken.

As preliminary suggestions, the following ideas are offered: The sands of the Benton or Graneros which outcrop in localities around the Black Hills and which are fairly consistent water producers in the eastern part of the State are likely to be found in many parts of western South Dakota, and should be good oil reservoirs. Also, the possibility of finding deep sands below the Dakota is considered good for a large part of the western part of the State. Although deep drilling will be required to test the older formations down to the Pahasapa limestone, such drilling is well worth while, for some of these lower beds are among the most dependable producers of oil in the Wyoming fields. The question of the extent of these beds is still open, but the increased cost in drilling for investigating their presence is not great in proportion to the increase in chance of finding oil on a favorable structure. As has been indicated above, certain general features of the geology of the State may be of help in predicting the extent of these rocks.

OIL AND GAS PROSPECTS IN SOUTHERN PERKINS COUNTY

INTRODUCTION

Following activity on the part of local newspapers, the area west of Faith, South Dakota, was heralded as a future oil field. Consequently, the State Geological Survey was very much interested in getting an opportunity to investigate the area in detail. In the spring of 1923, the people of Bixby offered to help in the work, and a party was put in the field shortly afterwards.

LOCATION

The area concerned in this report is located almost entirely in the north half of T. 14 N., R. 14 E., along the Moreau River in the southern part of Perkins County, South Dakota. The nearest point on the railroad is about 25 miles distant at Faith. The location of the area of this report with respect to the other areas described in detail in the State is shown by the index map (Fig. 1).

ACKNOWLEDGMENTS

The people of Bixby were kind enough to give some assistanace in the matter of transportation. H. N. Evans, Frank Beck, and J. Croughan deserve special mention for their help.

FIELD WORK

A party of two spent about six weeks in the field. During this time the geology was determined for the area as shown on the map (Fig. 2). The method of working was to use a telescopic alidade, plane table and stadia rod to run a continuous traverse over the field. Locations and elevations were determined for a large number of outcrops of a key bed in the upper part of the Fox Hills sandstone. By plotting the elevations on the map, the structure could be determined and contours drawn to show it. The horizontal control was checked by locating all of the section corners which could be found in the area, and by closing the traverse. A scale of two inches to one mile was used in the field work. In all cases the errors in location were less than 200 feet. The elevations at the start were based on an aneroid reading of the difference in elevation between a point in the area and the railroad station in Faith. From that time the elevations were carried by the plane table. In no case of checking a traverse were elevations in error as much as five feet. The greater number of the elevations used in the contouring are based on observations on the key bed itself, but in several cases beds were found in the Lance which could be used for shorter distances.

TOPOGRAPHY

The outstanding topographical feature of the region is the valley of the Moreau River. The valley varies in width up to a maximum of nearly two miles, and is crossed and recrossed by the meandering

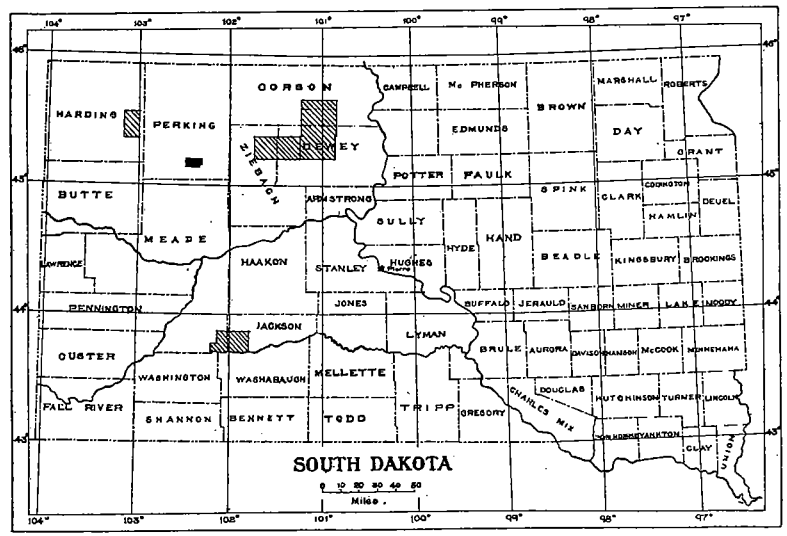

Fig. 1. Index Map

Black area refers to this report.
Shaded portions refer to other reports already published.

channel of the river. In general the sides of the valley rise about 100 feet above the river. Back from the sides of the valley there is a rise in level for a distance of one to four miles until the general prairie level is reached. The river valley and the valleys of some of the larger creeks include all of the area mapped.

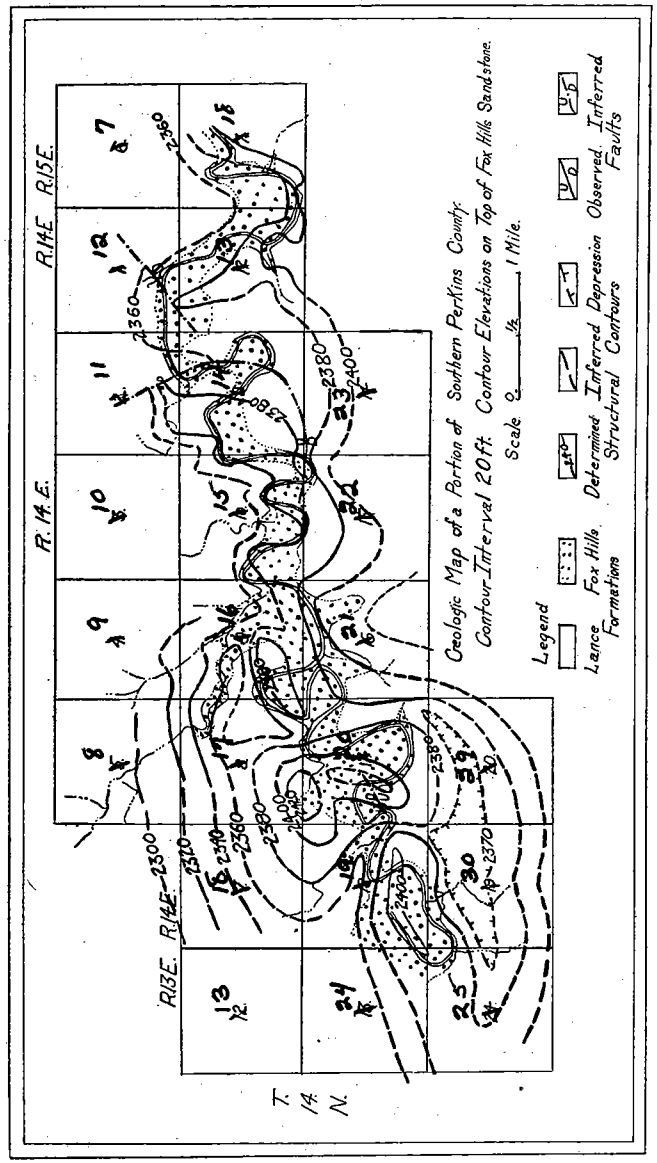

Fig. 2. Geologic Map

THE FORMATIONS

The oldest formation exposed in this area is the Fox Hills. In the region near Isabel, previous work has shown the Fox Hills there to have a total thickness of 200 feet or more. In southern Perkins County, however, the Fox Hills formation is not more than 100 feet thick. Although the base of the formation probably is not exposed, the transitional phase into the typical Pierre Shale was observed in several places. A section was measured along the bank of the Moreau River in section 16 of T. 14 N., R. 14 E.

Sandstone with thin bands of sandy shale, gray to yellow in color with some reddish streaks, and lenses of lignitic shale up to half an inch thick	4 feet
Shale—dark sandy (top of Fox Hills)	2 feet
Slab-forming sandstone, which is thinly laminated and has symmetrical ripple marks on the top (key bed)	6 inches
Alternating thin beds of sandstone and sandy shale	4 feet
Alternating thin beds of dark gray shale and sandy shale—some fossils	20 feet
Shale resembling the Pierre	10 feet

The Lance formation was not measured in this area. In general it is composed of two distinct members. The basal unit is made up of variable beds which in some cases have a very close resemblance to the Fox Hills formation and are composed of soft, light buff, crossbedded sandstones. In other places typical somber Lance beds immediately overlie the bed taken as the top of the Fox Hills. Lignitic shales up to 4 feet thick are found in these beds. The relation between the two types of material sugests that the buff sandstone was deposited before the somber beds and that a considerable amount of channeling followed, which made the surface irregular before the deposition of the somber beds. The somber beds are very irregular in their thickness and character, as would be expected for material deposited on so uneven a surface. The lignitic beds are local and erratic. Above the lower irregular beds there is a somewhat uniform series of dark clays and shales interbedded with layers of black ferruginous concretions. The top of this member was not seen in or near the area.

STRUCTURAL GEOLOGY

There is no considerable folding within the area. The structural conditions are about as reported by Wilson in his preliminary report on the "Oil and Gas Possibilities in South Dakota," which was published by the State as Bulletin 10. There are no domes or anticlines of great size, but small folds can be outlined by detailed mapping with the use of a key bed.

Even a casual examination of the map shows that the distribution of the different formations is more largely controlled by topography than any other factor and that the dips in general must be gentle. Since the area of outcrop of the key bed is limited to the

valley of the Moreau River and some of the largest tributaries, little information of high grade could be obtained about the area surrounding. It is known that the general dip of the region is north. By use of this fact and observations on beds in the Lance which could be followed locally, it was possible to extend the area of contouring somewhat.

The principal doming in the area seemed to be in sections 17 and 18 of T. 14 N., R. 14 E. On a line of folding here three domes are developed which have a maximum closure of about 40 feet. None of these domes is a sharp fold. The folding in the balance of the area produced only minor irregularities and did not result in closed domes or anticlines.

In the eastern part of the area there is some interesting faulting which starts near the southwest corner of section 11, T. 14 N., R. 14 E., and can be found at intervals across the section. The faulting may not be due to one single curved fault zone as shown on the map, but this interpretation seemed best because the character of the disturbance, the amount of displacement, and the direction of the fault all suggest continuity. The question of true faulting as contrasted with slumping is an important one in connection with the bearing of the structure on the possibilities of oil and gas accumulation. In the field both possibilities were kept in mind and the decision reached that the disturbance is a true deformation of the rocks, starting at some depth. The Moreau River at the present time is actively cutting its channel in the Cretaceous sediments. The faulting action extends to the level of the river, and yet took place long enough ago so that many of the open fissures formed in the action are now filled with calcite. These facts seem to indicate a fundamental rather than surficial disturbance. In addition, the displacement is in each case in the opposite direction to that which would be expected to result from slumping.

POSSIBILITY OF GETTING OIL IN THE AREA

As has been stated in the various reports of the State Geological Survey on the possibilities of oil in various portions of the State, the commercial accumulation of oil demands source material, a reservoir rock, and favorable structural conditions. It is considered probable that suitable reservoir beds will be found under this portion of Perkins County within drilling distance, and that the proper source material for oil is associated with them. The succession of formations which it is expected will be found is given below in the table (Fig. 3), taken from Circular 13 of the State Geological Survey.

There is a slight possibility that suitable reservoir rocks may be found in the Niobrara or Carlile, but no dependence should be placed on finding them until drilling has demonstrated their presence. The first fairly good chance of finding a reservoir bed is in the Graneros shale. Near the middle of this formation there is a sandstone which is known in the wells in many places in eastern South Dakota, where it commonly produces water. The sandstone

Cretaceous	Lance			75–100
	Fox Hills			100
	Pierre			1200
	Niobrara			200
	Carlile			300
	Greenhorn			25
	Graneros		400	225
		Mowry		25
				25
		Newcastle (Muddy)		25
				100
	Dakota			150
Comanchian	Fuson			50
	Lakota			200

Fig. 3

is also found around the Black Hills. Although this sand is known to be somewhat irregular in occurrence, it is general enough to merit serious consideration as a possibility. It is believed that this sand has the proper qualities for a suitable reservoir rock. The presence of the Dakota and Lakota sands can be expected with an even greater degree of confidence than is the case for any of the preceding.

The potency of water circulation through these sands to scatter any oil which might tend to accumulate is not known and possibly might be great enough to prevent their success as reservoir rocks. On the whole, however, they deserve serious consideration. The author's view is that the chances are good that the older formations which underlie the Dakota-Lakota group in the Black Hills underlie the region in question and that they are to be given a place among the possible oil bearing horizons. Oil production is obtained from several of these beds in Wyoming. Since there is no information giving a basis for a reasonable estimate of these beds in Perkins County, it will not be attempted. It is believed that these rocks

should be tested either to a considerable depth or until the rock character indicates that all of the formations in which oil could possibly occur have been passed.

Depth of Drilling.—The depth of drilling always depends on the location of the well. If a well were located in Section 17, T. 14 N., R. 14 E., a little west of the middle, there would probably be no more than 100 feet of the Fox Hills to be drilled through. The depth to the Niobrara would be about 1,300 feet, to the Carlile about 1,500 feet, to the Newcastle about 1,900 feet, to the Dakota about 2,200 feet, and to the Lakota about 2,400 feet. It is advisable, if possible, to drill about 800 to 1,200 feet more into the formations underlying the Lakota, or until the rock character shows that the Pahasapa limestone has been reached or will not be found. Although the total depth suggested here would be about 4,000 feet, if the formations below the Lakota have the thickness that is found around the Black Hills, and may not be practical under the present conditions, it is recommended because of the reliability of some of the lower formations in producing oil where structural conditions are favorable. Certainly no test should be stopped before drilling conditions prevented further work, unless oil had been found or the old crystalline rocks reached. Otherwise a test would not be final in condemning the region.

Prospects of the Region.—As has been indicated, the presence of reservoir rocks and source material is reasonably certain. The principal point for speculation is the type of structure which will be effective in causing the accumulation of oil and gas. This can be determined only by an extensive and careful drilling program. Doming or faulting,—or better, both together,—are likely to control oil accumulation if it has taken place at all in the State. From these considerations it is believed that the drilling of a small dome such as the one mapped in this area in Section 17 is an average good wildcat proposition, and that in spite of the hazards and uncertainties, it is to be seriously considered as a speculation. Favorable parts of the area are the dome in the west half of Section 17. Other structures which present some possibility but which are slightly less favorable are the dome in the southern part of Section 18 and in the SW¼ of Section 9. The faulted areas in Section 11 and in the SW¼ of Section 1 also deserve consideration. If these faults can be shown to intersect, as the field evidence suggests, a point north of the intersection and lying between the faults might be a very favorable location for drilling. The valuation to be placed on one of these localities as compared with another is difficult to determine, but an attempt to do this is made in the following section.

Possible Drilling Sites.—In case speculation is to be made to the extent of raising funds for drilling a test well in this region, the following locations are mentioned as being of first choice of the area mapped: the center of the SE½ of the NW¼ of Section 17; NE cor. NW¼ of NW¼ of Section 17, and the NE cor. of the SW¼ of the SW¼ of Section 1. All locations are in T. 14 N., R. 14. E.