South Dakota
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VERMILION
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The Possibilities of Oil and Gas in Harding County

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Introductory

Interest in oil and gas in this state still runs high despite the lack of any big finds to date. Considerable inquiry has been made concerning the N. W. part of the state. To meet this demand the past field season was devoted to a study of the region.

This circular records the chief facts that have been determined to date, and presents the theoretical side of the question in a general way. Further field work is necessary before anything more positive can be said. The problem will probably never be entirely settled until, in addition to the field work, a few deep holes are put down

No attempt is made to give references to the literature or quote authorities. Thorough and complete treatment of the problem is reserved for a later Bulletin.

Harding County is in the extreme N. W. corner of the state.

Much that is stated herein can be applied equally well to other parts of N. W. South Dakota outside of Harding County.

General Geology

Areal Geology.

The rocks of this region are all of sedimentary origin. Probably four-fifths of the county is covered by the Lance. This consists essentially of clays and shale with local beds of sandstone. Beds of lignite

Geological Section for Northwestern South Dakota

Formations			Thickness (in feet) Max.	Min.	Ax.
Tertiary		Arikaree	225	0	125
		White River	140	0	75
		Ft. Union	425	0	150
Tertiary? Cretaceous?	Lance	Cannonball Marine	100	0	50
		Ludlow Lignitic	350	0	300
		Lower	425	0	350
Cretaceous		Fox Hills	100	25	65
		Pierre	1500	1300	1400
		Niobrara	200	150	175
	Benton	Carlile	800	600	700
		Greenhorn	50	25	35
		Graneros	1200	800	1000
		Dakota	120	40	80

are also common in parts of this formation. None of the strata are widely persistent; rather, variation is the rule both vertically and horizontally.

In the N. E. part of the County and further west in the Cave Hills and Table Mountain the surface material is Ft. Union. In the Slim Buttes and Short Pine Hills—S. E. and S. W. parts of the County respectively—the Arikaree and White River occur. The first two formations are made up predominantly of sandstone. The latter is chiefly clays.

There is a small area of Fox Hills (sandstone) in the N. W. part of the County. And along the extreme southern part of the County Fox Hills again is present together with slightly larger tract of Pierre (shale).

No attempt is here made to give a detailed description of these formations.

Columnar Section.

Below these surface formations it is known that other formations occur. In the table (page 2) is given the typical geological section for N. W. S. Dak. The youngest formation is placed at the top, the oldest at the bottom, and the others in orderly sequence between.

No attempt is made to list the Comanchian or older rocks, for they have little bearing on the problem.

Sructure.

The term structure refers to the attitude or position of the beds. The type of structure most favorable for the occurrence of oil and gas is the anticline. The importance of structure in oil and gas investigation calls for a careful consideration of this subject in reference to the area in question.

The Plains Region.—Throughout the Plains region, of which Harding County is a part, the beds are essentially flat. If they were absolutely and uniformly flat there would be little to say further. But such is not the case.

The largest structural feature—as marked by the position of the Dakota sandstone—is an immense synclinorium, some 250 miles across and 500 miles long. This trends N. W. and S. E., reaching from Saskatoon, Canada, down through eastern Montana and western N. Dak., and into northern S. Dak.

Of lesser dimensions but still a major feature is the Black Hills uplift, whose main axis also trends N. W. and S. E.

On the northern flanks of the Black Hills, in southern Butte County and N. E. Wyoming, distinct anticlinal structures are present with a N. W. and S. E. trend. In eastern Montana a well marked anticline—the Glendive or Cedar Creek anticline—again trends N. W. and S. E. A syncline parallels it on the S. W., followed in turn by another anticline. Both of these, however, are not as well marked as the Glendive structure.

Anticlines trending N. W. and S. E. occur also in N. Central Montana.

In northern N. Dak. another low but distinctly marked anticline is known—this trends north and south.

It seems clear, then, that the general flatness of the Plains strata is relieved by the presence of open folds, which almost uniformly trend in some N. W. and S. E. direction, less commonly north and south. These are known in northeast Wyoming, in eastern Montana and in N. Dak.

Harding County.—One of the important parts of the problem is to determine how far the local structure of Harding County responds to the larger structure of the region.

The N. E. part of the County is considered by the Federal Survey to have the structure of a basin-like syncline whose axis is further east in Perkins County. The dips are very low,—7 to 65 feet per mile. It is possible that careful field work may bring to light some local flexures, though no strongly marked anticlines with dips over 5 degrees can be expected. In fact, an examination of the Cave Hills area shows that the North Cave

Hills are on an anticline whose axis is approximately along their S. W. edge and which trends N. W. and S. E.: while the South Cave Hills have a position in the contiguous syncline. The dips in each case are low, being not over 50 feet per mile.

The Glendive anticline trending S. E. cuts across the S. W. corner of N. Dak. and is known to enter S. Dak. in a modified form in Harding County, Range 2 east. It has lower dips and is less plainly marked than in Montana. Just how far it reaches into the county can only be determined by further detailed field work.

In the S. W. part of the County just south of the West Short Pine Hills there has been reported another low arch again trending N. W. and S. E.

The presence of these several low flexures suggests that others will be found upon close inspection.

Two weeks' time was spent in a restricted area in the N. W. part of the County,—Towns 21 and 22 N., Range 1 E—where the rock exposures were fairly good. Plane table and level were used.

It is clear from this work that in this particular locality the structure does respond to the larger feature of the region, for the strata in general strike N. W. and S. E. Furthermore, a fairly well-marked domnal anticline was located in Section 8, T. 21 N., R. 1 E. The dips are again low, but are considerably higher than those in the east part of the County. The maximum dip observed was 3 degrees.

It is believed that further work done with the proper care will bring to light other anticlines in the County, some of which may be more strongly marked than those so far discovered. Only a little has been accomplished so far. Most of the County has yet to receive this close scrutiny.

Tertiary vs. Cretaceous Structure.—There still remains another phase of the structural problem to consider: viz,—does the Lance-Tertiary structure of the surface faithfully reflect the Cretaceous sructure below? This is critical because the oil and gas—if present at all—are to be expected in the Cretaceous rather than the other.

The date of the major deformation—such as the main Black Hills uplift and the formation of other large folds—has usually been given as the close of the Cretaceous.

The Lance-Tertiary was then deposited, probably following a period of erosion. This means that the folds now seen are of a still later date. It means further, that well-marked folds in he Cretaceous may now be covered by flat-lying or but slightly deformed Lance-Tertiary beds. Some deformation is known to have occurred also in Tertiary time. It is possible, too, that the deformation may have occurred so late in Tertiary time that the oil and gas previously accumulated in older structures has not had time or opportuniy to get into the newer structures.

While some doubt may legitimately exist in regard to these matters, probably the most satisfactory answer to this question—at least for this N. W. region—is the condition of the Glendive anticline. This is a well-marked anticline; it has the prevailing trend; the Lance-Tertiary beds and the Cretaceous below are deformed as a unit; and the field is a productive one.

It can be reasonably concluded that in this region the surface Lance-Tertiary structures are a safe index of the deeper structure.

Faults.—In so far as the County has been examined it can be said that there is a general absence of faults. The occasional fault encountered is local and of small dimensions.

Surface Evidence of Oil and Gas

No oil seepages or scums, no gas springs, no asphaltic substance, etc., have been found by this Survey. A number of cases of scums have been reported. These have been examined in so far as that was possible and none of them have been indicative of oil or gas. As far as is known there is no authentic case of surface evidence of oil or gas in the County.

The entire absence of surface indications of oil and gas does not necessarily mean an entire absence of those substances deeper down. In fact, there is every reason why they should not reach the surface—assuming that they are present below—for the oil and gas horizons of this region are in the Cr taceous and the thick cover of dense, impervious Pierre Shale would naturally prevent any upward escape. Cracks and openings in the overlying Pierre might let the oil and gas work towards the surface, but there seems to be a general absence of such fractures.

The absence of surface indications is an entirely negative piece of evidence.

Other Evidence of Oil and Gas

Relation to Wyoming and Montana Fields.

The belief that oil or gas may exist below the surface in this County has arisen because in the neighboring states of Wyoming and Montana both oil and gas have been found. The value of this relation depends on the distance from the nearest producing fields, the correct correlation and possible variation of the same strata in the given distance, and other factors.

It must not be forgotten that this is a pure assumption, and it must not be accepted as valid without due consideration of what it involves.

Wyoming.—The nearest productive field in Wyoming is the Moorcroft field in the N. E. part of the state. It is 70 miles from the nearest part (S. W. corner) of Harding county. It has never reached quantity production and at the present time it is rated as non-productive. The chief oil horizon is the Graneros. There are other anticlines in Wyoming nearer to S. Dak. These are now being explored.

Until oil or gas is struck in commercial quantity in the N. E. corner of Wyoming, the relation between Harding county and the Wyoming oil field can only be considered suggestive: it should cause no excitement nor create any strong hopes of success.

Montana.—The nearest productive field in Montana is the Baker field, which is 35 miles from the nearest part (N. W. corner) of Harding County. This field is already productive of gas (no oil yet) on a commercial scale and bids fair to increase in importance very decidedly. It is located on the Glendive anticline already mentioned. The gas horizon is a sandstone bed in the Pierre.

The Baker field is an important one. It is not an extreme distance from Harding County. The anticline on which the field is located reaches into Harding County. All this does warrant some assumption that gas (and possibly oil) may be found in the County either on the main anticline itself or some of the smaller ones adjoining, providing any other factors do not interfere.

Correlation of Strata.

Another factor in the problem must be considered before the assumption can be carried any further. The oil and gas horizons in Wyoming and Montana are in the Cretaceous. Are we sure that these same strata are present below the surface in Harding County?

Since the Cretaceous as a whole—Pierre, Dakota, Benton, etc.,—is known to be wide spread, has been encountered in all directions away from Harding County, and indeed is present in part along the edges of the County itself, we feel sure that it must underlie the whole County.

But this fact does not satisfy the whole condition of correlation. The variations that are known to be developed in Wyo. and Mont. may or may

not be present in Harding County, and these variations are apt to be critical. For instance,—the Pierre, which is known to be in all three states, and in Harding County, has a variation of importance. In all of S. Dak. where it is well exposed and known from top to bottom, it is uniformly and persistently a shale. This is true in the type locality—central part of the state—and in the region north of the Black Hills, in Butte County. Further west sandy beds appear in this shale. The gas horizon in the Baker field is a sandstone bed in the Pierre. In central Wyo. the Parkman, Teapot, and Shannon sandstone are members of the Pierre formation. Similarly the Benton equivalents in Wyo. are the prominent and productive Frontier and Wall Creek sandstones.

It is known that these sandy members thicken toward the west and thin towards the east: they are known to be prominent in central Wyo. and eastern Mont. and absent in central and western S. Dak. At just what point in western S. Dak. or eastern Mont. and Wyo. they begin to be effective is not known,—and this is a critical point in the problem. If it can be shown that the Cretaceous along the western edge of Harding County is the same as it is 100 miles east, then there is little use in being concerned about oil in S. Dak.,—and vice versa. The Pierre in Butte County has some porous limestone lenses. It is barely possible that these may act as reservoirs of oil and gas though little can be expected from them in this capacity.

The only way to decide whether the Cretaceous of Harding County does or does not contain these important sandstone members is by trial. A deep hole—preferably several holes—must be put down, abundant samples taken, a careful log kept, and all the data turned over to someone competent to interpret it.

Field Work

As has been intimated, a great deal of work needs to be done in the field before the exact structural conditions are known throughout the County. This field work must be careful and detailed if it is to yield results.

The difficulties of the field are several.

In the first place there are rather large tracts which have a nearly continuous sod cover with scarcely any outcrops. The desired data are not visible. Wells are so few in number, so shallow, and so widely spaced that they are of little help.

Another difficulty is the character of the rocks themselves even when well exposed. Instead of the well marked continuous Cretaceous beds, such as occur close around the Black Hills, or in central Wyoming for instance, there are the poorly marked, lense-like Lance-Tertiary beds. This makes the finding and tracing of index beds a much more difficult matter.

A third difficulty lies in the fact that the dips are low. This requires careful work with a good level rather than approximate work with hand level and clinometer.

Finally, there are no satisfactory base maps of the County. A good, large-scale topographic map would be a tremendous help.

Because of these difficulties field work must progress slowly.

Depth to Productive Horizons

If we accept the assumption that oil or gas, or both, exist underneath this area, then, the probable depths to the productive strata should be calculated.

There are four horizons that need to be considered in this connection:

1.—The Pierre. In the Baker field gas is struck approximately 1100 feet below the top of this formation.

2.—Greenhorn. The important Frontier in central Wyo. is in an equivalent position. It is very doubtful whether there is a single sandstone in the Greenhorn of this region but its depth can be calculated.

3.—Graneros. The sandstone bed which in the Moorcroft field yields oil is in the lower part of the formation, in this region probably 750 feet below the top.

4.—Dakota sandstone.

The depth to each horizon depends on (a) the thickness of the formations (b) which particular formation is the surface material at a given locality, (c) how much of this surface formation has been removed by erosion.

The table (page 2) gives the thicknesses of each formation in feet and arranged in three columns,—maximum, minimum, average. The Tertiary and Lance have zero in the minimum column. This is because they are the surface materials and in parts of the County have been removed by erosion and so are entirely lacking.

Since no measurements have ever been made on the Cretaceous in the County the figures given are based on the nearest data in S. Dak., Mont., and N. Dak. As a consequence, they cannot be rated as absolutely accurate for this County. However, they must be reasonably near the truth.

Naturally the depths to the four horizons will vary, depending upon the locality chosen. A few illustrations will make this point clear.

Suppose an estimate is to be made in T. ~~22~~ N., R. 2 E., Sect. ~~16~~. The surface material here is the Fox Hills. Some of it has been removed by erosion, how much is not known exactly. But probably 50 feet will fairly represent the probable thickness of that which remains. Horizon No. 1 can be expected, then, after 50 feet of Fox Hills and 1100 feet of Pierre are are penetrated,—at a depth of 1150 feet from the surface. No. 2 will be reached after 50 feet of Fox Hills, 1400 feet of Pierre, 175 of Niobrara, 700 feet of Carlile are penetrated, or 2325 feet from the surface. The depth to No. 3 is ascertained by adding to this figure 35 feet of Greenhorn and 750 feet of Graneros, which makes a total of 3110 feet. Similarly horizon No. 4 will be reached at 3360 feet from the surface.

If the dome located in Sect. 8, T. 21 N., R. 1 E., be the place chosen, the depths will be greater, for all the Fox Hills is present plus some of the lower Lance which is the surface material there. The center of this dome is in a badland tract which has been considerably dissected. It is difficult to tell how much has been removed by erosion, but it is believed that about 100 feet stil remains. Horizon No. 1 should be expected, then, after 100 feet of lower Lance, 65 feet of Fox Hills and 1100 feet of Pierre are penetrated, or a total of 1265 feet. Similarly No. 2 should be expected at 2440 feet, No. 3 at 3235 feet, and No. 4 at 3485 feet from the surface.

If a hole is to be put down on the top of the Cave Hills the depths to the various horizons would have to be increased 800 to 1000 feet, for the surface is the Fort Union. Below it the Cannonball Marine member of the Lance is absent, but the Ludlow Lignitic and Lower members of the Lance are there in toto.

Each locality in the County will have some modification of the figures given above.

Summary

1.—The absence of surface evidence is a negative argument; it neither supports nor refutes the belief that oil or gas is present.

2.—The expectation of oil or gas in this area is based on its proximity to the productive Wyo. and Mont. fields. The actual distance from the former is considerable, but from the latter not excessive. The relation to the Wyoming field is only suggestive. But the Glendive anticline of Mont. is known to enter Harding County and so does give a reasonable hope for gas (and possibly oil) in S. Dak.

3.—It is not known whether the Cretaceous strata below the area have beds porous enough to act as reservoirs even if oil or gas is present in the formations. Further west this favorable condition exists, further east it is known to be absent.

4.—Field examination of the area shows structure paralleling the Glendive anticline, but with lower dips. A fairly well marked dome was found, which is one of the favorable locations for putting down a hole. Other anticlines will probably be found: they are more likely to occur in the western than in the eastern part of the County.

5.—It is believed that there is a reasonable chance of striking gas (and possibly oil) in the County. The most favorable places for putting down holes are on the Glendive anticline itself and the smaller anticlines in the adjoining area, one of which has already been located.

6.—But success cannot be promised. In an entirely new field the results from the first hole are always the most difficult to predict. Until the first hole is put down the uncertainty is bound to be marked. If success is attained the pecuniary returns will be high. If no oil or gas is encountered the data from such a pioneer hole will always be a distinct contribution to scientific investigation, and in either case the information gained will aid tremenduously in guiding the placing of the next hole.

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