SOUTH DAKOTA AS AN OIL PROSPECT

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To the question "Is there oil in South Dakota?" the answer is "Yes." When it is phrased to read "Will South Dakota produce oil?" the answer must be that we do not yet know. So much progress has been made toward finding the answer to this latter question, however, that I am making bold to bring it to the attention of the Academy.

In the early days of the industry, oil was found by the hit and miss method of drilling wherever anyone had a hunch and enough cash to back it. In most cases the hunch consisted of vigorously asserting that in the new location the hills were as high or the ground as flat or the bushes as green as they were back in Blank County where oil was being produced.

Soon, however, it was discovered that oil pools were tied up definitely with certain kinds of rock and certain rock structures, and those whose drilling program followed these natural laws had fewer dry holes, more money in the bank, and in general were more influential citizens than those who went at it by the old and expensive hit and miss method. So firmly has the idea of geologic relationship to oil become fixed in the minds of the industry and the public that little drilling is now done without some investigation into the geology of the situation. The first step, therefore, in answering our question concerning South Dakota is to find out what geological conditions obtained in the state which could make oil or gas and collect it into pools from which it can be extracted in commercial quantities.

There are three essentials for an oil pool, namely, a source rock in which oil originates, a reservoir rock in which it accumulates, and a trap which keeps it from escaping.

In shallow water lagoons, estuaries, and quiet bays of the ocean, live myriads of plants and animals from whose bodies petroleum or a wax-like substance from which petroleum can be extracted is formed. This oily or waxy substance adheres to the mud and limey oozes which are being precipitated on the ocean floor.

Rocks of this type, formed from the mud and lime, which contain oil or which might have contained oil at one time, are known to the oil profession as source rocks since they are the rocks which furnish petroleum to the oil pools. Without source rocks somewhere in the section, a region has a very slim chance of having producing pools.

The second requirement, the reservoir rocks, are rocks of coarser grain than the shale which allow oil to move freely through them by gravity just as does the ground water. They are usually sandstones or cavernous limestones and oil is forced into them from the source rock because capillary openings such as those in the shale exert a greater pull on water than they do on oil. Most source rocks are porous sandstones, with inpervious layers of shale lying over them. Such a combination allows oil entering the sandstone to move freely through it while the caprock prevents its escape.

The third necessity for an oil pool is the trap. Once in the reservoir rock, oil being lighter than water tries to rise to the surface. Since it cannot move vertically because of the caprock it finds its way up the dip (slope) of the rock strata until it is stopped by some change either in the reservoir itself or in the slope up which the oil is travelling. In the case of the pitch lake on the Island of Trinidad there is no trap and the oil escapes at the surface, there to be dried to tar as its lighter constituents escape into the atmosphere.

In some cases a fault or slip in the rock seals off the reservoir rock by bringing impervious shale opposite it. Oil cannot move beyond this fault and, therefore, accumulates as a pool between the caprock and the fault plane.

The third and most common type of trap is a fold in the rock strata, commonly called an anticline or, in the oil vernacular, a "structure." Through these structures oil collects by moving up the dip from both sides and there separates into three divisions, the lightest materials, the gases, occupying the top of the inverted basin, underlain by the oil pool which in turn is underlain by salt water.

With this brief resume of the origin and accumulation of oil let us turn to the geology of South Dakota and see which of these features it has to offer, keeping in mind that all three factors, the source rock, the reservoir, and the trap must be present, or there is less possibility of accumulating oil than there would be of holding water in a bucket with a short stave.

Ever since geologists have first visited the state they have been interested in the character of the sedimentary rocks and though their studies had to be confined largely to those which outcropped at the surface considerable information had been gathered before any deep drilling had been done. The thickest section of exposed sedimentaries outcrops about the Black Hills, where the deep-lying beds have been brought to the surface by mountain folding and erosion. This section shows four groups of rocks which are of interest from a geological standpoint.

The youngest sedimentaries rest on a foundation of Pre-Cambrian rock. These are hopeless as oil producers since some of them are volcanic, offering a poor abode for the volatile and inflammable material which makes petroleum. Others have been recrystalized under tremendous heat and pressures, precluding any possibility of oil remaining in them if it had ever been there. Pre-Cambrian rocks outcrop in the core of the Black Hills and also at the foot of Big Stone Lake and in a large area between Mitchell and Sioux Falls. Pre-Cambrian rock has been struck by water wells in a number of places east of the Missouri river.

When these rocks are encountered it should be a signal to drillers of oil tests that the end has come for that well. Oil has never been produced from pre-Cambrian rocks and their origin offers a good reason why it will never be.

In the Black Hills outcrops a series of Paleozoic and Mesozoic sands, shales and limestones offers some interesting horizons since some of them are possible source and reservoir rocks. Worthy of mention in this connection are the thick Paleozoic limestones belonging to the Pahaspa (Mississippian) and associated formations. This limestone has given shows of oil in the Red Canyon well, and in a

water well drilled in Rapid City. It is cavernous and would make an excellent reservoir rock if its outcrop characters continue underground. The Pennsylvanian (Minnelusa) formation is typical of the system. It has alternating streaks of limestone, sandstone, and shale averaging from 5 to 10 feet in thickness. Its lower part has given shows of oil at a number of places about the Black Hills.

Above these formations lies a series of red beds, mostly sand stones and shales, with here and there lenses of snow white gypsum. These red beds are not interesting because of oil possibilities since they so far have been barren in this vicinity. The brick red color, however, and the presence of gypsum are excellent markers by which these beds can be identified from cuttings of wells which penetrate them.

The next zone of interest is the sandy zone (the Dakota, Fuzon, Lakota formation), which furnishes the artesian water for so much of the state. In Wyoming it has produced oil and gas, and along the upper Missouri in South Dakota it produces gas.

Above the Dakota zone lie Cretaceous shales, some of which are known to contain oil. The Burning Bluff near Wheeler is such a zone, which is so full of petroleum that at one time it was sold for coal. Oil has also been distilled from these shales in the Big Sioux Valley east of Elk Point and near the School of Mines in Rapid City.

In this Mesozoic section there lies a persisent zone of chalk some 200 feet thick which makes a doughnut of poor outcrops about the Black Hills and a long stretch of dirty grey, cream colored and white cliffs along the Missouri Valley from Fort Thompson to Yankton. This rock, (the Niobrara formation) furnishes small amounts of gas in Charles Mix county and south of Chamberlain. At Ponca, Nebraska, it gave a small showing of oil.

It is evident from this cursory examination of the outcrops that source rocks occur in South Dakota. The abundance of sand exhibited by the section shows that there are plenty of reservoir rocks. The next question, whether these rocks underlie enough of South Dakota to make an interesting oil prospect, is only partially answered. The answer

has to come from properly placed wells which penetrate all the sediments down to the pre-Cambrian rocks. Very few such wells have been drilled in our state however, but the few deep wells we have give some hint as to what may be expected at least in the western half of the state.

An intresting well was drilled by the Gypsy Company in 1931, 25 miles north of Wall in Meade county. An excellent record including cuttings was furnished the State Geological Survey. This well showed the presence of red beds and a heavy limestone with intervening sediments which correlated very well with those outcropping in the Black Hills, and thus carries the Black Hills section 50 miles eastward under the plains. A significant difference is the presence of gypsum beds in the Minnelusa (Pennsylvanian) formation, indicating a shore phase of this formation which does not occur in the Black Hills. It is possible that this is part of the basin which connects with southeastern Montana, since a similar Pennsylvanian section was found in a well drilled in that site 15 miles northwest of the corner of Harding county.

A second important well was drilled by a local company at Standing Butte in Stanley county, 30 miles northwest of Pierre. The drillers recorded artesian sands, red beds, and heavy limestones in the same approximate position in which they occurred in the Gypsy Company's well. Between these markers the drillers record beds which correspond to the section occurring around the Black Hills. This well, then, carries the Black Hills section with its source and reservoir rock nearly to the Missouri River and is especially interesting since these rocks thin out and disappear on the pre-Cambrian highlands which outcrop at Mitchell and which have been struck by the drill at Iroquois.

Oil wells drilled farther north by J. S. Cosden, one at Zeal in northeastern Meade county, and another at Red Elm in Ziebach county, reached the red beds, thus corroborating the evidence of the two wells already mentioned. From this information, therefore, it may be expected that rocks similar to those outcropping in the Black Hills can be encountered at most points west of the Missouri River. They may underlie a large section between the Missouri and James Rivers north of Huron since a well in North Dakota not so far from Aberdeen gave a section of Paleozoic rocks underneath the artesian horizon. Heavy limestones have been found at Sioux City but apparently do not occur in the state in Charles Mix county. Thus about two-thirds or three-fourths of the state is underlain by rocks which would justify testing for oil.

Now let us consider for a moment the last of three requisites mentioned at the beginning of this paper, namely the traps. Thanks to the artesian sands in our state we have some very definite information on the general structure. Plotting the elevation of the artesian sands over the state brings out the fact that the pre-Cambrian rocks east of the James River acted as buttresses against which the forces which folded the Black Hills acted. Thus there was formed, between the Black Hills and this buttress, a great trough or geosyncline (the Lemmon geosyncline) which pitches rapidly toward North Dakota. The center of this trough passes through Philip and Lemmon taking a northwestward direction parallel to the folding of the Black Hills and the Rocky Mountains.

On the sides of such big troughs or basins we find most of the oil fields of North America. From a drilling standpoint, therefore, the interesting features will be the smaller structures on the flanks of the Lemmon syncline. Very little has been done in searching out these minor folds, largely because the exposed rocks are of such a character that it is very difficult to find key beds. Recent work of the Survey has enabled us to make divisions of the Pierre formation which cover a large part of this territory. On these divisions it is now possible to map structure.

The little detailed mapping that has been done has shown that small structures do exist on the flanks of the geosyncline. In the northwestern part of South Dakota there are a number of **en echelon** folds which continue the structure of the Baker field in Montana. Some of these have been mapped in Harding county. South of the Hills in

Fall River county there are also a group of small folds, some of which have been mapped.

The east side of the geosyncline is still virgin territory. The first mapping attempted was done last summer, by a survey party, in the vicinity of Pierre. This showed broad, low undulations running in a general northwest southeast direction, lying across the flat terrace at the edge of the geosyncline. Gas occurs on this terrace from Pierre north to the state line and is a favorable indication since its collection appears to be controlled by this major structure.

The problem thus far has been one largely of geological research and most of that problem is still with us. The progress which has been outlined has come about as the result of the geological labors of a long list of South Dakota geologists and has resulted in a picture which has shown the light in the other end of the tunnel. We know the general geological situation and what sort of rocks the driller should encounter in most parts of the state.

Future prospecting for oil will have to consist of a careful search for small structures in favorable locations along the flanks of the great geosyncline and a drilling program comprehensive enough to adequately study them. We have in the state large areas which are still virgin territory. Both the eastern and western sides of the Lemmon syncline offer excellent prospecting and as geological information is accumulated countless new favorable areas will be encountered which are now entirely unknown. In the light of our present knowledge there are only two areas which can absolutely be ruled out as oil prospects. One is the center of the Black Hills; and the second about 1800 square miles between Mitchell and Sioux Falls, possibly including a strip along the eastern border of the state.

It is only a matter of time until the depletion of the larger fields and the increasing difficulty of finding new supplies will drive prospectors into our state, and if we are wise we will be ready for them when that time comes, and so prevent South Dakotans from being tricked by oil sharks and encourage the orderly and efficient exploitation of whatever supplies of this important fuel may be discovered.