SOUTH DAKOTA

GEOLOGICAL AND NATURAL HISTORY SURVEY

E. P. Rothrock, State Geologist.

REPORT OF INVESTIGATIONS

No. 7.

THE POSSIBILITIES OF OIL AND GAS IN WESTERN POTTER COUNTY

By

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Vermillion, S. Dak.

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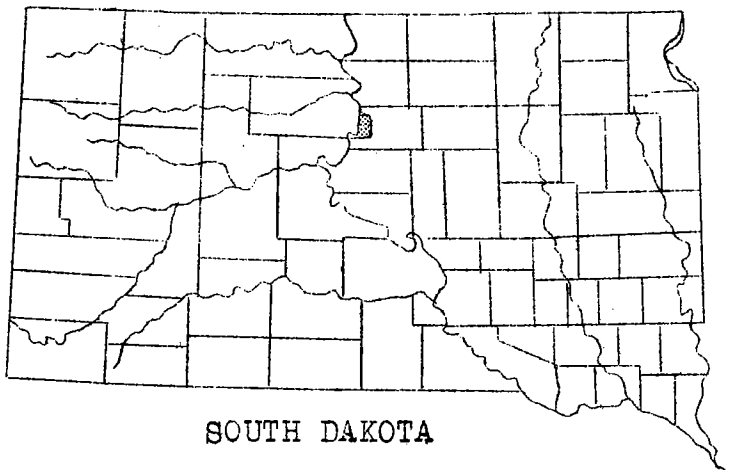
PREFACE

Mr. William L. Russell investigated the area covered by this report in the summer of 1925, under the direction of Doctor Freeman Ward, then State Geologist. The manuscript was submitted and accepted by Doctor Ward but never published because of lack of funds. Recent interest in the oil and gas possibilities of this region however, has prompted Mr. Russell's report available in this form.

E. P. Rothrock
State Geologist



SOUTH DAKOTA

Fig. 1 Index Map

Black portion shows area covered by this report.

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LOCATION

The area described in this circular comprises about 80 square miles in western Potter County and in addition a narrow belt along the Missouri River in southeastern Dewey County. Most of the area is included in T. 118 and 119 N., R 77 W., though small portions of the adjacent townships were also examined. The most promising structure found in the region is fifteen miles west-northwest of Gettysburg, a town and railroad station on the Chicago and Northwestern Railroad. Fig. 1 shows the position of the area mapped.

ACKNOWLEDGMENTS

Acknowledgments are due to Mr. M. L. Thompson, of Vermillion, who furnished the survey party with lodging, transportation, and subsistence, and to Mr. J. H. Williams and others of the Potter County Land and Abstract Co., who assisted the work in various ways. Mr. E. B. Mayo acted as instrument man during the plane table work.

FIELD WORK

During the course of the investigation a study was made of the artesian well records in order to ascertain whether they could be used for mapping structure, and also to obtain

an idea of the character of the unexposed rocks down to the Dakota sandstone. Aneroid elevations of many of these artesian wells were obtained, in order to work out the structure and nature of the Dakota sandstone, and for use in studying the artesian conditions. Various horizons in the Pierre shale, which forms the bed rock of the region, were examined, in order to ascertain if they contain suitable key horizons for use in mapping the structure. After the presence of a reliable series of key beds in the Pierre had been established, a structure map was constructed by means of a plane table and telescopic alidade. About two months were spent in the field.

TOPOGRAPHIC AND FIELD CONDITIONS

The area consists almost entirely of rolling prairie, with woods and trees along the larger streams. The lowest elevations in the region are of course along the Missouri River in the southwestern part, where it is about 1450 feet above sea level. The highest elevations in the territory covered by the structure map are slightly over 1950 feet, along the range of buttes and hills which extends in a north-northwesterly direction to the northeastern corner of S. 21, T. 119 N., R. 78W. There is thus a range in elevation of over 500 feet.

Water for drilling might be obtained from the Missouri River, about four miles distant from the top of the structure, from the Goodburn artesian well, about two and a half miles distant, or from Little Cheyenne Creek, about a mile and a half distant. Little Cheyenne Creek might not furnish enough water during dry spells, however.

STRATIGRAPHY

A. The Exposed Rocks

The exposed rocks of the area consist of the Pierre shale, glacial materials, alluvium, and loess. The loess materials are important to the oil geologist chiefly, because they interfere with the mapping, and because they tend to produce slumping. In the areas of steep slopes, where the Pierre shale is covered with glacial materials, slumping is especially pronounced, because the rain water, seeping through the pervious glacial materials, collects at the surface of the Pierre shale, and renders it very elastic.

The glacial till covering the region east of the area mapped is doubtless of late Pleistocene age, for it has been but little eroded, except in the immediate vicinity of the larger creeks. The late Pleistocene glaciation apparently did not extend over most of the area mapped. Glacial till covers the range of hills which extend in a north-northwesterly direction from the northeast corner of section 34, T. 118 N., R.78 E., and it also covers Patchskin Buttes, which are west of the Missouri River and northwest of the area mapped. Hills five miles west of LaPlant, and about 22 miles west of the western border of the area mapped, are also capped by glacial till. The terminal moraine of this early Pleistocene glaciation appears to have extended through LaPlant in a nearly east-west direction. Boulders of igneous and metamorphic rocks carried in by the glaciers lie scattered over the prairie in the area north and east of this terminal moraine, but none may be seen southwest of it. Immediately south of the southern limit of the boulders in the vicinity of La Plant there is a distinct channel about half a mile wide, which marks the temporary course of the Missouri River during the maximum advance of this earlier Pleistocene glaciation. About five miles slightly north of west of LaPlant, where the channel crosses the divide between Virgin Creek and Moreau River, it is at an elevation of about 2100 feet. Several miles slightly south of east of LaPlant, where it crosses Fox Ridge, it is at an elevation of about 2000 feet. The evidence that the glaciation responsible for these isolated patches or till was earlier than that which laid down the sheet of till east of the area mapped is that much more erosion has taken place since the deposition of this sheet of till than since the deposition of the latest sheet of till. In the area mapped and west of the Missouri River all of it except a few patches of till on the highest elevations and occasional scattered boulders have been removed. As Patchskin Buttes and the range of hills in the area mapped are approximately parallel to the ice front, they may be kames or moraines due to the temporary readvances of the glacier.

The Stratigraphy of the Pierre Shale is as follows:

Top

Soft bluish-gray shale, containing brownish concretions, 75 to 100 feet.

Shale, soft, in part calcareous, containing numerous concretions which have a peculiar "Worm Eaten" appearance. These are one to two inches long and generally about half an inch to an inch in diameter. They are gray or grayish-yellow in color and are penetrated by numerous minute holes

like worm borings. In addition to these concretions, there are in many places at this horizon small, cylindrical concretions, grayish-white in color, with a soft core which often dissolves away, leaving hollow cylinders that resemble the stems of large clay pipes. Belemnite shells, which are cigar shaped and composed of fibrous calcite with a radiating structure are also rather common in this shale. The "worm-eaten" concretions are often formed about ammonites, bacculites, or pelecypods. The remains of crabs or other arthropids may also occur sparingly at this horizon. This formation is called bed WE by the writer. Near its top there are in places lenses of light gray chalky shale ten or fifteen feet thick, though no good exposures of these were found in the area examined. About 20 feet below the top of the member there is a layer or layers of cone-in-cone, which is apparently about 80 feet above bed 00 below. Bed WE is apparently about 80 feet thick, though this is not known definitely because the upper portion is poorly exposed.

Shale, bluish gray, 20 feet.

Shale, containing the oolitic concretions, which are oval, generally 3 to 7 inches long, bluish-white or grayish-white, with peculiar chipped or cracked outer surfaces, and with an oolitic structure within. A few oolitic concretions also occur among the lower "Worm-eaten" concretions, but they may be distinguished from those at this horizon by their smaller size and associations. At the base of this member is a bed of large, flat concretions, composed of hard, bluish gray limestone, weathering brown, which are frequently traversed by parallel cracks which cause them to split into thin parallel plates in weathering. This member is about 20 feet thick and is called by the writer bed 00.

Shale, bluish gray, soft, containing dark brown or purplish-black ferruginous concretions, 110 feet.

Shale, composed of alternating light and dark layers. The lighter layers are slightly harder, and this causes the outcrops to weather in a steplike fashion. In places the shale is slightly calcareous or chalky. The bones of the Mosasaurus Clidastes atrox Marsh, and Tylosaurus proriger Cope were found in this member. These were identified by Dr. M. R. Thorpe. This member may be called bed LD. It is about 30 feet in thickness.

Shale, hard, fissile, very light gray, which weathers into loose plates and chips, which lie about in the soil. In this respect it differs from the shales above it, which generally weather into a gumbo or soft clay. At the top of this member is a zone of large, grayish white limestone concretions, some of which contain large inocerami and plates of fibrous calcite. This member extends up the Missouri River to within a few miles of the mouth of the Moreau River, down the Missouri below the mouth of Cheyenne River, and some distance up Cheyenne River. It appears to be of sufficient importance to receive a separate name, and the writer has accordingly called it the Agency shale, from Cheyenne River Indian Agency, where it is well exposed. Its exposed thickness is about 120 feet.

Base of Section

The best key horizons for mapping the structure are the colitic concretions, forming bed 00, the top of the Agency shale member of the Pierre, and the cone-in-cone horizon in bed WE. The cone-in-cone horizon is probably about 80 feet above bed 00, and bed 00 is about 160 feet above the top of the Agency shale. Most of the elevations on which the structure map is based were taken on top of bed 00.

In areas of complicated structure and poor exposures, such as the region under consideration, it is rather difficult to determine the thickness of the zones in which the different concretions used as key beds occur. It will doubtless appear to the geologist beginning an investigation of the region as though bed 00 and the cone-in-cone concretions occurred in zones about fifty feet in thickness, for the outcrops of these concretions are often found to differ by that amount within short distances. When, however, the complicated character of the structure is taken into consideration, it appears that some of these differences in elevation are due to the influences of the structure, and that the concretions which form bed 00 do not occur in a zone of such thickness. Owing to the poor exposures at the cone-in-cone horizon, the thickness of the zone in which they occur is not definitely known. The general type of structure is not apparent at the horizon of bed 00, because of the poor exposures, but it may be plainly seen on the bluffs and badlands on the west bank of the Missouri River. Fig. 4 shows the general nature of the structure in this region.

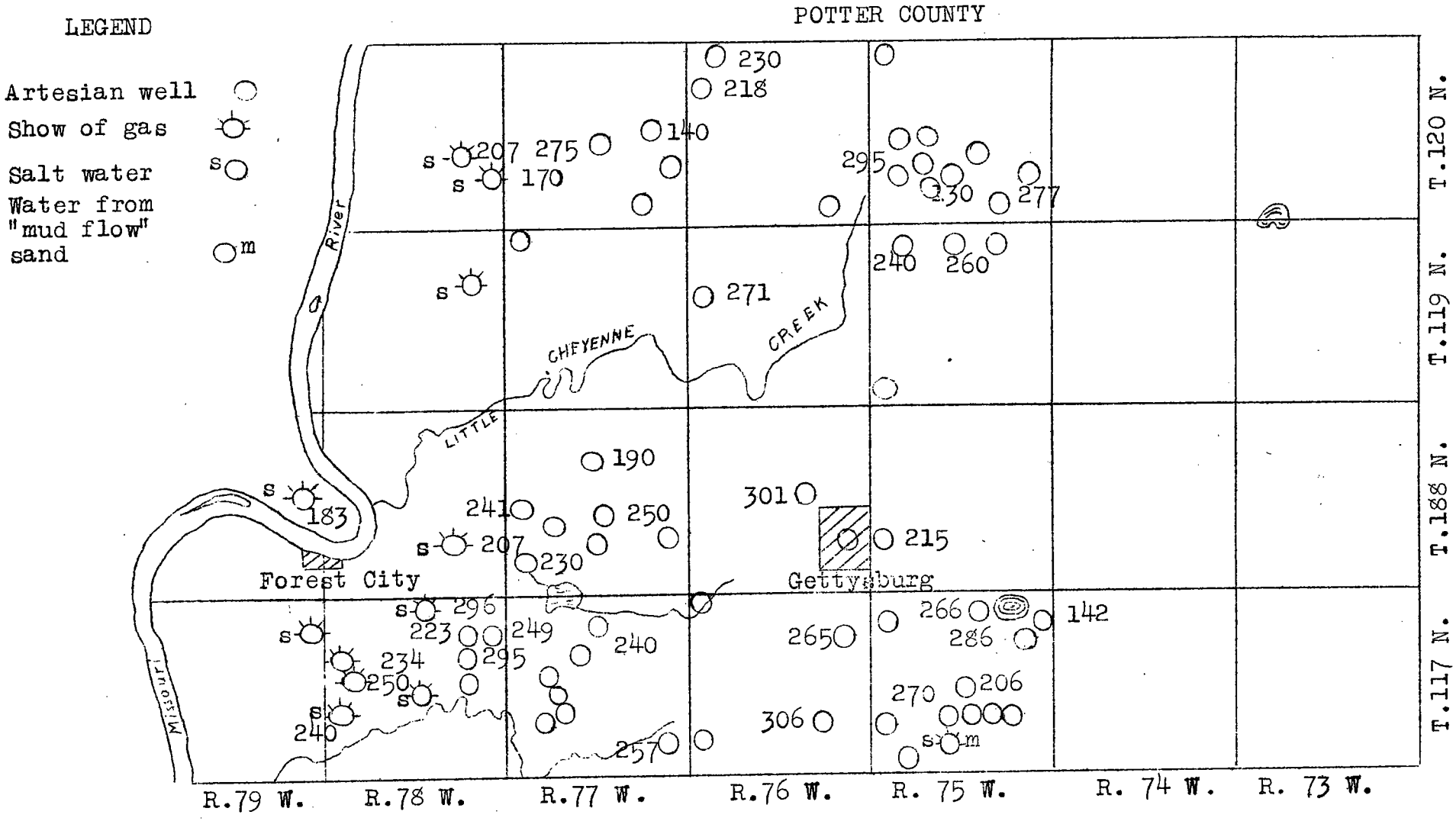
B. The Unexposed Rocks

Knowledge of the unexposed rocks of the region must be obtained from the records of the artesian wells in the vicinity, and from the logs of the few wells which have been drilled for oil. A fair idea of the general character of the strata down to the Dakota sandstone may be obtained by this method, but very little is definitely known about the nature of the rocks below this. The only well in the immediate vicinity which penetrated through the upper portion of the Dakota formation is the Fox well, several miles northwest of Gettysburg and about ten miles east of the structure. According to a record of this well given to the writer from memory, the top of the Dakota sandstone was found at 1760, and at about 2100 to 2130 a very hard red rock was penetrated. From about 2130 to 2260, the formation is said to have been bluish gray shale, with a showing of heavy dark oil. The total depth of the well was about 2260. The country in the vicinity of the well is completely covered with glacial materials, and it would have been impossible to obtain any clue to the structure in that locality. The only well in this part of South Dakota which is known to have penetrated the formations below the base of the Cretaceous is the Standing Butte well, about 35 miles southwest, which has passed through 1100 or 1200 feet of rocks below the base of the Cretaceous rocks. The estimates of the character of the pre-Cretaceous rocks are therefore based chiefly on the log of this well, and on the supposed regional variations in the character and distribution of the formations.

The following table gives an estimate of the character and thickness of the subsurface rocks of the area:

Table of the Subsurface Formations of the Area; beginning 120 feet below the top of the Agency shale member of the Pierre shale:

Name	Character	Thickness in feet
Pierre shale	Shale, gray and bluish gray shale, black, harder	350 50 to 100
Niobrara formation	Shale, bluish gray, calcareous or chalky	50
Carlile shale	Shale, chiefly bluish gray	400
Greenhorn limestone	Gray limestone, fairly hard, called "cap rock" by artesian well drillers	0-50
Graneros shale	Bluish-gray shale	350-400
Dakota formation, with possibly the equivalents of the Fuson and Lakota formations at the base	Soft, porous sandstones interbedded with shales	300-600
Unkpapa Sundance	Sandstones, and greenish and reddish shales	Probably absent
Carboniferous, Minnelusa?	Bluish-gray, pink and black shales interbedded with thin limestones and sandstones	0-400
Mississippian and older?	Limestones, chiefly gray	0-800
Ordovician or Cambrian	Shales, sandstones or limestones	0-200
Pre-Cambrian	Igneous or metamorphic rocks	great



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Circular 29 Figure 2

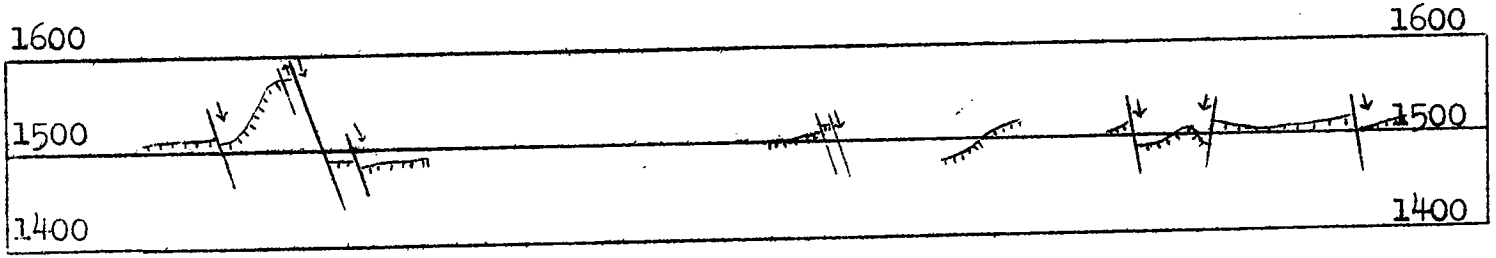
Showing height of Dakota sandstone in artesian wells. Figures show elevation of top of Dakota sandstone above sea level.

South Dakota Geological and Natural History Survey

Vermillion-July, 1926

CIRCULAR 29, Fig. 3.

TOP OF AGENCY SHALE MEMBER OF PIERRE SHOWN THUS

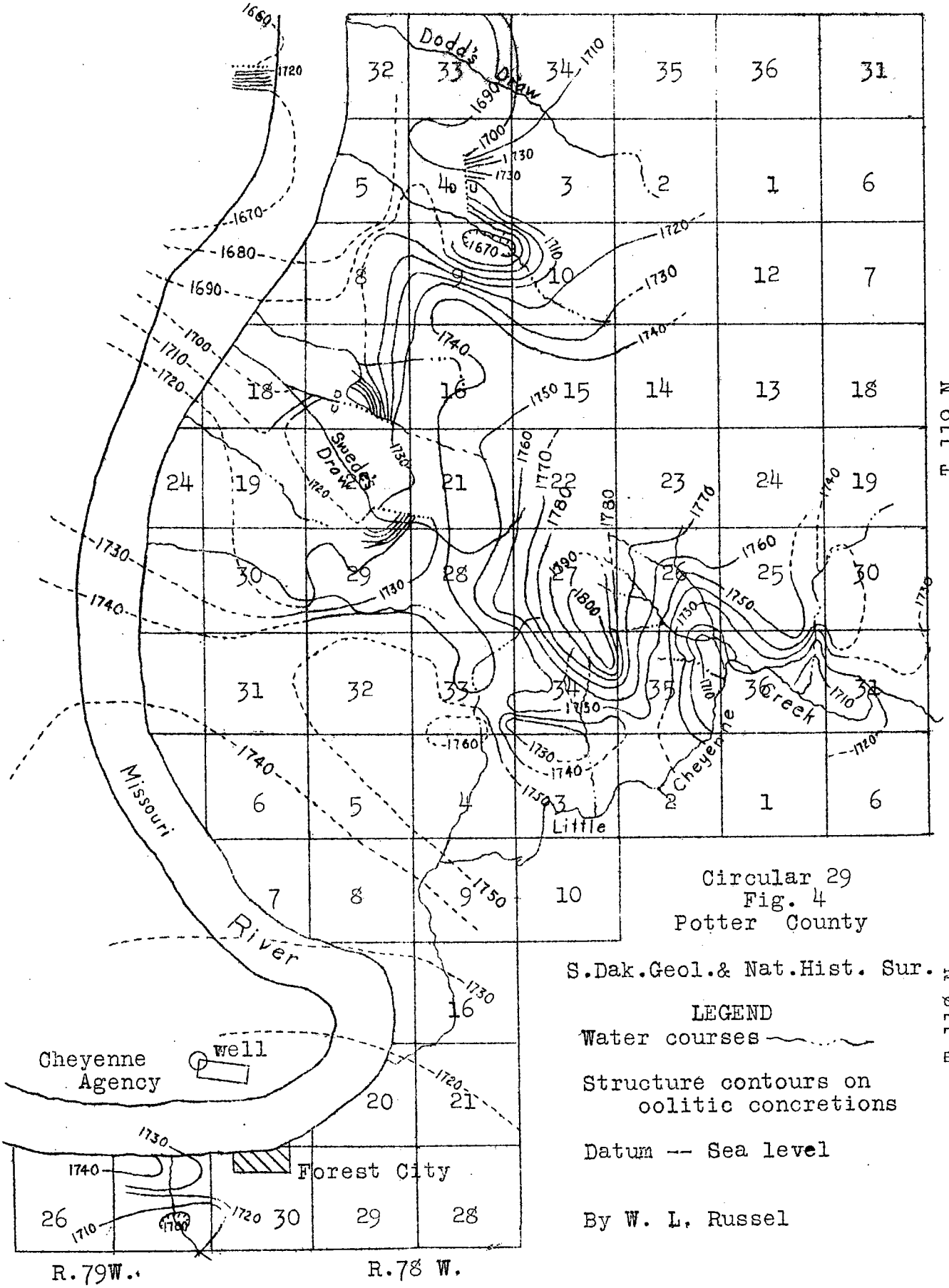


0 1000 2000 3000 4000 5000 Feet

Horizontal scale

SECTION ON WEST BANK OF MISSOURI RIVER OPPOSITE MOUTH OF STEAMBOAT CREEK

IN N.W.POTTER COUNTY


Dodd's Draw
Swede's Draw
Missouri River
Cheyenne River
Little
Creek
Cheyenne Agency
well
Forest City
T.119 N.
T.118 N.
R.79W.
R.78 W.
Circular 29
Fig. 4
Potter County
S.Dak.Geol.& Nat.Hist. Sur.
LEGEND
Water courses
Structure contours on oolitic concretions
Datum -- Sea level
By W. L. Russel

It should be understood that the so-called Dakota sandstone is not single definite, persistent bed of sandstone, but rather a thick series of more or less lenticular sandstones interbedded with shales. The top of the Dakota sandstone as reported by artesian well drillers is in reality at different horizons. Fig. 2 shows the elevations of the reported top of the Dakota Sandstone in a number of artesian wells in western Potter County. As the elevation of the reported top of the sandstone differs by 170 feet and varies in a highly irregular fashion, it is obvious that what is reported as the top of the sandstone is not always at the same horizon. Some of the differences in elevation may be due to faulting and folding, but only part of the irregularities can be accounted for in this manner. It is obvious, therfore, that the top of the Dakota sandstone, as reported in artesian well records, cannot be used to map the structures. The investigations of the Dakota sandstone made by the writer on the outcrops to the east and west tend to confirm this conclusion.

It is at present impossible to say definitely whether the Paleozoic rocks underlie the area, or whether the pre-Cambrian rocks lie immediately beneath the base of the Mesozoic, but the former alternative seems to the writer to be the most likely. The reasons for this supposition are the great thickness of Paleozoic rocks found in the Standing Butte well 35 miles southwest, and the occurrence of Paleozoic strata beneath the Cretaceous in northeastern North Dakota. It is probable that the major part of the erosion which removed the Paleozoic rocks from eastern South Dakota took place in late Jurassic or early Cretaceous time. The general dip of the Paleozoic strata is west or northwest, and it is likely that the lower Paleozoic formations extend further east than the upper Paleozoic formations, which were the first to be eroded away. Consequently the formations at the base of the Paleozoic section are more likely to underlie the area than those at the top. A well starting on the top of the structure at the horizon of the cone-in-cone bed would probably enter the Dakota sandstone at a depth of about 1800 or 1850 feet, though, as the first sand is not always at the same horizon, the depth may vary considerably from this estimate. The top of the Paleozoic series, if present, should be encountered at about 2400 to 2500 feet.

STRUCTURE

The general structure of the area is shown in Fig. 4. It is almost obvious at a glance that it is quite complicated, and if all the individual details of the deformation were shown it would be much more complicated. These small folds and faults, which are very numerous, are not shown on the structure map, for they could not be represented on the scale used, and moreover they cannot be worked out over most of the region, owing to the absence of good exposures. Such details probably do not presist down to

the horizon of the oil sands, and hence there would be little use in mapping them. A general idea of the nature of these minor structures may be obtained from Fig. 3, which is a detailed section along the west bank of the Missouri River opposite the mouth of Steamboat Creek, in the northwestern corner of the area covered by Fig. 4. There are in many places sharp dips of several degrees caused by these small folds and fault blocks, and in a few places the dips are over five degrees. These steep structures are not due to slumping, for they show no relation to the topography, and many of them are of such a nature that they could not possibly have been formed by slumping. They are not due to the shoving of the glaciers, for they occur at the base of deep ravines and cliffs cut out since the last period of glaciation, and moreover they extend beyond the limits of the glaciated area. The faults are all or nearly all normal, and the fault planes commonly dip towards the axes of the small anticlines. Reversed drag, which has been described in more detail by the writer in Circular 20, is of common occurrence, as is shown by Fig. 3.

The regional dip of the strata at the surface in this portion of South Dakota is north or north-northeast into the deep basin or geosyncline in western North Dakota. This dip is interrupted by an extensive anticline or regional arch which extends in an east-west direction near the crest of Fox Ridge, and which may be called the Fox Ridge Arch. The crest of this arch runs through the central part of the area mapped. It is known to extend from the eastern part of the area mapped across the Missouri River and along Fox Ridge to the west for a total distance of about 80 miles.

It should be remembered that, owing to the increase in intervals towards the west, the regional dip of the formations at the horizon of the Greenhorn limestone and the Dakota sandstone is different from that of the strata at the surface. The egional dip of the Cretaceous rocks below the Greenhorn limestone is probably northwest. It is possible that the structure of the Paleozoic rocks would differ considerably from that at the surface, though there is at present no definite evidence as to this point.

Several smaller structures are superimposed on the Fox Ridge arch, the largest of which lies in the eastern portions of sections 27 and 22, and the northeastern portion of section 34 and section 23, all in T. 119 N., R. 78 W. The closure of this anticline is not accurately known, because of the uncertainty as to the interval between bed 00 and the cone-in-cone horizon, and because of the absence of exposures to the northeast. If the interval between the cone-in-cone horizon and bed 00 is 80 feet, as was assumed in drawing the structure contours, then the structure is closed to the extent of 60 feet in all directions but the northeast, and is probably closed to the extent of 40 feet in this direction.

OIL AND GAS POSSIBILITIES

In estimating the oil and gas possibilities of the structure the following factors must be considered:

1. Reservoir rocks
2. Source rocks
3. The nature of the structure and its adequacy to produce an accumulation.
4. The possibility of artesian circulation
5. Oil and gas shows in the region.

1. Reservoir Rocks:

Many sandstones which are sufficiently porous and permeable to produce oil and gas in commercial quantities underlie the structure. The first possible horizon is the unnamed sand from which the "mud flow" of the artesian well drillers is obtained. As it is apparently of a lenticular nature, however, it might not be encountered in the test well. The Dakota sandstones and the sandstones in the Lower Cretaceous formations which may lie below them also contain several fairly thick and highly porous sands, though in some places they may run together and form a single, very thick sand. The Carboniferous formations penetrated in the Standing Butte well also contained several porous sandstones, and it is therefore likely that this formation contains them in the area under discussion, if it has not been removed by pre-Cretaceous erosion. In the Black Hills region and other localities there is at the base of the Paleozoic limestones a series of sandstones and shales, but there is no means of determining whether this series is present at the base of the Paleozoic in this locatlity, for the Standing Butte well has not yet been penetrated to this horizon.

2. Source Rocks:

It is generally supposed that oil usually originates in bituminous strata which are nearly always of marine origin. Often these bituminous rocks are of a dark color, but the best method of recognizing them is to distill them in a closed tube. If much oil is present it will form a ring around the tube. In order to form an oil pool of commercial size, the source rocks should be closely associated with the reservoir rock, or there should be a fault or fissure permitting the oil to migrate from the bituminous source rock to the porous reservoir rock. As no samples of the shales associated with the Dakota sandstones are available, it is not known whether or not they are suitable for forming oil. Some of the dark bluish-gray or black shales were

found in the Carboniferous shales in the Standing Butte well, and the writer tested several samples of these in a closed tube. It was found they did not give off any visible amount of oil, but emitted a bituminous or oily odor. Only a small portion of the total thickness of these shales was tested, however. It seems likely that these Carboniferous shales, if present, contain some bituminous material, but whether the amount and the association with the sandstones are suitable for the formation of commercially productive oil pools can only be determined by drilling.

3. The Nature of the Structure and its Adequacy to produce Oil Accumulation.

The dips on the structure are generally from one half a degree to one degree, and while these are not as steep as is usuall the case with the oil pools in Cretaceous rocks, it should be remembered there are many oil poolsin Cretaceous strata which produce from structures of this nature. Moreover, the best prospects are not in the Cretaceous formations, but in the Paleozoic rocks beneath them, and it is generally supposed that such steep dips are not necessary to produce oil accumulation in the Paleozoic formations.

One of the most favorable features of the structure is that it is located on the crest of an extensive regional arch. Since so many oil pools, especially in areas of low dips, are located along the crests of regional arches, it is evident that structures located on the axes of such arches are much more likely to produce.

4. The Possibility of Artesian Circulation

Artesian circulation is supposed to be unfavorable for the occurence of oil. At all events, the sands in which there is artesian circulation generally contain fresh water, and oil is rarely found in sands that contain fresh water outside the limits of the oil pools. It is generally supposed that the artesian waters of eastern and central South Dakota have migrated under the state from the Black Hills or the Rocky Mountains, and that this movement is still continuing. If this were the case, the possibilities of oil and gas in the Dakota sandstone in western South Dakota would not be so promising, for the artesian circulation might sweep away the oil and gas pools.

It appears to the writer, however, more likely that there is no artesian circulation in this region. It is probable that the Dakota sandstone is too lenticular to permit the waters to flow through it for such great distances, and furthermore the head or altitude to which the water would rise in wells does not always increase towards the west. In fact, according to Darton's figures, the head was slightly lower at Cheyenne Agency than at Gettysburg, 18 miles east. The elevations of the artesian wells obtained by the writer indicate that at the present time the head varies in an irregular fashion, being generally lower in

the areas where the greatest amount of water has been used. The maximum amount of variation is about 100 feet. Figure 2 shows that there is a fairly definite boundary between the area along the Missouri River in which slightly salty water with gas is encountered in the Dakota sandstone, and the area further east in which potable water without gas or with the merest traces of gas is found. If the waters were moving from west to east, such a difference in the nature of the waters would not be found. For these and other reasons the writer concludes that there is no appreciable artesian circulation in this region. Even if there is a slight circulation, it is probably too feeble to destroy the oil and gas pools or prevent their formation, and it is likely that, owing to the lenticular nature of the Dakota sandstones, many of them would escape the artesian circulation in any case.

Though the water found in the Dakota sandstone along the Missouri River is commonly described as "salty" it is not as salt as the ocean or as the salt water found associated with the oil in most oil fields. It is however, not so fresh as to indicate that oil and gas will not be associated with it in commercial quantities. The water found in the Standing Butte well in the sand near the base of the Cretaceous was quite fresh, and the water from the basal sand of the Minnelusa (?) was also fresh. This is a rather discouraging feature for production in these horizons.

5. Shows of Oil and Gas

In most of the oil fields of the country oil shows are found in the rocks which produce oil when they are penetrated outside the limits of the pools. Hence the fact that a considerable number of wells in this vicinity have been drilled through the "Mud Flow" sand just below the Greenhorn limestone and the upper portion of the Dakota sandstones without finding any shows of oil, as far as could be learned, suggests that oil is not likely to occur in these sandstones in commercial quantities in this area even on a structure. On the other hand, as all wells in the vicinity of the structure found shows of gas in the "MudFlow" sand and the upper portion of the Dakota sandstones, it is possible that a pool of gas will be found in the structure in these formations. Shows of oil are said to have been found in the Dakota sandstone in the Standing Butte well and in a well on Plum Creek in eastern Haakon County, but these wells are further west than the structure under consideration. Shows of oil were also reported in the Minnelusa (?) formation in the Standing Butte well.

Conclusions as to Oil Possibilities

In conclusion, it may be stated that there appears to be a reasonable possibility of obtaining oil on the structure in T. 119 N., R.78 W. The Cretaceous rocks are much more likely to pro-

duce gas than oil, though there is a slight possibility that oil will be found in these strata, this possibility seems remote, because the artesian wells in the area found no oil. The most promising formation for oil production is the Carboniferous sandstone, probably equivalent to the Minnelusa sandstone of the Black Hills. Hence the test well should be prepared to penetrate to the base of the Minnelusa (?) series, which will probably be encountered at a depth of about 2800 to 2900 feet, though if there has been an extensive pre-Cretaceous erosion of the Paleozoic strata it may be found at lesser depths. The structure may be considered quite favorable, as the anticline has a fair closure, and is located on the axis of a regional arch, but the uncertainty as to the presence and character of the Paleozoic rocks and the presence of fresh waters in some of the possible horizons add to the risks, which are always great in a wildcat venture.

GENERAL CONCLUSIONS

1. A series of reliable key beds for mapping structure has been found in the middle and upper portion of the Pierre shale.

2. A structure which covers several sections and which may have a closure of 40 feet has been mapped.

3. This structure is located on the crest of a regional arch, which makes its oil possibilities much more promising.

4. This is the only oil and gas structure known in South Dakota east of the Missouri River.

5. Although the structure is a few miles east of the Missouri River, the conditions are typical of the country west of the Missouri.

6. It is not likely that there is enough artesian circulation in the Dakota sandstones in the area to destroy the oil and gas pools or prevent their formation.

7. Gas may be found in the structure in the Cretaceous rocks. While there is a slight possibility that oil will be found in these strata also, the indications for it are not promising, owing to the absence of oil shows in neighboring wells.

8. While there appears to be a reasonable chance of finding oil in the Paleozoic rocks, it is not definitely known that these are present in the area, or what their character is if they are present. Hence the risks of wildcatting in this area are great.