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Geological and Natural History Survey
Freeman Ward, State Geologist

CIRCULAR 23

Oil and Gas Possibilities in Northeastern Meade 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.

INTRODUCTION

The following report is based upon the detailed study of the structural and other geologic features of a small area in northeastern Meade County by the State Geological Survey during the season of 1924.

The primary purpose of the field studies was to determine whether structures were present in this area which would merit testing for oil and gas in the light of the present geologic evidence relative to oil possibilities in this part of the State.

LOCATION

The area included in this report lies in northeastern Meade County, about 25 miles southwest of Faith, the terminal town of a branch line of the C., M. & St. P. R. R. running out from Mobridge.

The mapped territory includes all of T. 10 N., R. 14 E.; the southern part of T. 11 N., R. 14 E.; the western part of T. 10 N., R. 15 E.; the eastern part of T. 10 N., R. 13 E.; and the northern part of T. 9 N., R. 14 E.

Cooper and Opal, two inland post offices, are located in the eastern and northwestern part of the area respectively.

The index map (Fig. 1) shows the location of the area in the State.

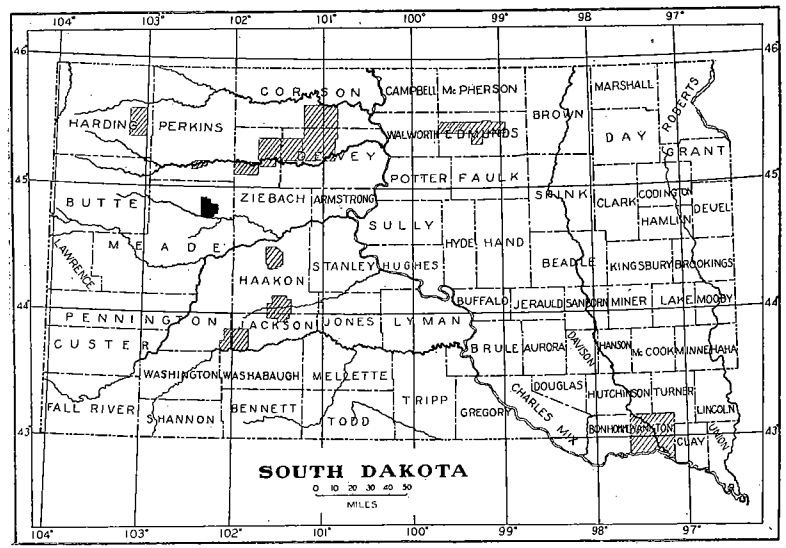

Fig. 1.—Index Map

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

FIELD WORK

The entire area was mapped with the plane table and telescopic alidade on an approximate scale of two inches to the mile. Horizontal control was determined by stadia, and the Beaman stadia arc method was used in establishing the elevation of all key bed outcrops and stations. A series of flying levels run by aneroid from the railroad station at Faith to a point in the area served as a starting point for the elevation readings.

The mapping was carried on by running stadia traverses along the trends of the outcrops of the several horizons which were used as key beds. Owing to the fact that the topography over much of the mapped area is characterized by rolling, grass-covered divides and shallow valleys, it was found necessary to use three distinct key beds, as no single key bed has continuous exposures. In fact, over a considerable part of the area the key bed exposures are unsatisfactory for mapping purposes.

Three thin layers of hard sandstone, each having distinctive lithologic features, were used as key horizons. These lie in the middle and upper part of the Fox Hills formation, the outcrops of which cover practically all of the area considered in this report. At least one of these key formations was found to be exposed in any given part of the area and in numerous localities two or all three were exposed. Since the three horizons have approximately the same stratigraphic position in all parts of the area, each key bed served as a convenient check on the others. It was thus possible, in spite of the generally unfavorable exposure conditions, to make a structure map which at least approximates the true structural conditions.

To serve as a further check on the structure mapping, sections of the strata were measured wherever sufficiently exposed, and any horizontal or vertical changes in the character or position of the key horizons were noted and compensated for, as far as possible, in the mapping.

ACKNOWLEDGMENT

The writer was assisted in the mapping by Kenneth Sprague, who rendered valuable and efficient service as instrument man. Mr. George O. King, of Faith, and Robert Pech, of Cooper, assisted in the work by providing transportation, by rodding, and by rendering other services which were of material aid in carrying on the field studies.

FORMATIONS

Pierre.—The typical dark blue shales of the Pierre first began to appear in the bottoms of the deeper valleys southeast of the area mapped.

Lance.—The basal, carbonaceous beds of the Lance cap several of the higher ridges in the extreme northern part of the area. In no place, however, are the Lance beds more than a few feet in thickness.

Fox Hills Formation.—In view of the fact that this formation is so well developed in this area and differs materially in lithologic and stratigraphic features from its characteristics where previously mapped by the State Survey to the north and east, a detailed description is in order. For description of this formation in other areas, see especially Circulars 9, 13, and 14, of the State Geological and Natural History Survey.

Following is a generalized section for the Fox Hills in this area:

1.	Sandstone, soft, grayish brown	25 ft.
2.	Sandstone, hard, coarse, medium gray to brown, weathering in platy or rounded masses. Contains buff, clay layers	5 ft.
3.	Sandstone, soft, light gray, with thin layers of shale	15 ft.
4.	Shale, carbonaceous, local lignite beds	10 ft.
5.	Sandstone, soft, light gray, massive beds	20 ft.
6.	Sandstone, hard, medium grained, sparkling texture due to micaceous fragments; weathers into a coarse rubble	5 ft.
7.	Sandstone, soft, very light gray	20 ft.
8.	Sandstone, hard, light gray with micaceous fragments; weathers into corrugated masses	5 ft.
9.	Shale and sandstone, light gray	20 ft.
10.	Sandstone, hard, weathering to a deep brown	3 ft.
11.	Shaly sandstone	10 ft.
12.	Sandstone, fine grained, buff weathering, hard, friable texture; platy layers of brown sand at top part	3 ft.
13.	Sandstone, shaly, light gray to yellow	15 ft.
14.	Shale, sandy, somewhat variegated	10 ft.
15.	Sandstone, hard, with intermixed clay; weathers into biscuit shaped masses	3 ft.
16.	Shale, light gray or drab, with thin sand layers	20 ft.
17.	Sandstone, with drab shale layers, yellowish	30 ft.
18.	Shale, sandy and variegated	30 to 75 ft.
19.	Dark blue, Pierre-like shale	5 ft. plus

As will be noted from this section, the thickness of the formation varies from 250 to approximately 300 feet. The above section is more typical of the central and northeastern parts of the mapped area. Towards the southwest, the basal part becomes more shaly and the upper part is characterized more by massive, light colored sandstones. When compared with sections measured in areas previously mapped by the Survey, it is to be noted that the formation becomes increasingly sandy towards the southwest, indicating an approach towards a shore line. This fact is further sustained by the increasing abundance of shallow water markings, especially ripple marks, towards the southwest. In the area studied the formation tends to thicken towards the southwest, suggesting an approach towards the area from which the sediments were derived.

One of the interesting features of the formation in this area is the presence of lignite seams in the upper part of typical Fox Hills strata. Several mines have been opened up on these coal beds a few miles southwest of the mapped area. The occurrence of these beds indicated that the transition into the conditions of terrestrial sedimentation typical of the overlying Lance formation was gradual and not marked by any intervening period of uplift and erosion. In view of this fact it is difficult to establish any exact boundary between the Fox Hills and the overlying Lance formation.

At no place in the area under consideration was the contact of the Fox Hills with the typical Pierre shale found exposed, but the contact probably lies just below horizon 19 in the appended detailed section.

As previously stated, the key beds used in mapping the structural features were hard sandstone layers in the middle portion of the Fox Hills formation. The horizons numbered 2, 6, 8, 12, and 15 were found to be especially persistent and constant in stratigraphic position. Of these key formations horizon 12 was found to be especially valuable and distinctive both from the standpoint of widespread occurrence and uniformity of characteristics. Most of the elevations were taken on this key bed.

Over the central and northern parts of the area the Fox Hills erodes into a rolling, grass covered country, but towards the south and west, where the upper part changes into more massive sandstones, the erosive features are characterized by narrow valleys, exposed ledges and knobs of light colored sandstone.

STRUCTURAL GEOLOGY

As indicated in the structure map (Fig. 2), the detailed structural features of this area are rather complex. In its broader analysis the structure of this region is characterized by a series of moderate to gentle folds which form a series of undulations with two distinct axial trends; northeast-southwest, and east-west. The east-west folds are the most conspicuous and have the steepest dips. At the point of intersection of these two sets of folds numerous small domatic uplifts and synclinal depressions have been formed.

The two most conspicuous structural features of the area are the broad anticline which extends east-west through the southern part of T. 10 N., R. 14 E., and the syncline which parallels it through the central part of the township. The above described anticline has several small, but distinct, domes superimposed upon it at the points where north-south trending folds cross it. The most important of these domatic uplifts are the two which occur on the eastern part of this anticline in the southeastern and southwestern part of sections 27 and 26, and the northeastern and northwestern part of sections 33 and 34. The writer considers these two areas as the most important from the standpoint of possible drilling sites.

The anticline at this general point has a distinct closure of about 60 feet and a probable closure of 70 feet. As indicated on the map, however, about 30 feet of this closure is included in the domatic uplift, the remaining portion including the broad, main anticlinal fold. The average dip in this area of greatest closure varies from 70 to 40 feet a mile. Over the region as a whole, the average dip is generally less than this.

The writer considers the other domatic uplifts which are scattered over the area as of less value from the standpoint of oil structures, but in the event of oil being discovered in this region they would all merit attention.

As indicated on the structural map, the regional dip is somewhat east of north, the general elevation of the key bed horizon changing from about 2,570 to 2,470 feet over a distance of approximately ten miles. This would give an average regional dip of 10 feet to the mile, which is quite typical of the plains region of western South Dakota.

DRILLING SITES

On the basis of the structural features discussed above, the most favorable location for a test well for oil and gas in this area would be on the high point of the domatic uplift which is developed in the S. E. ¼ of the S. E. ¼ of section 27 and the W. ½ of the W. ½ of the S. W. ¼ of section 26, T. 10 N., R. 14 E. Another location of less value from the standpoint of structural features would be the dome lying just to the west of the above location and which covers the northeast part of section 33 and the northwest part of section 34.

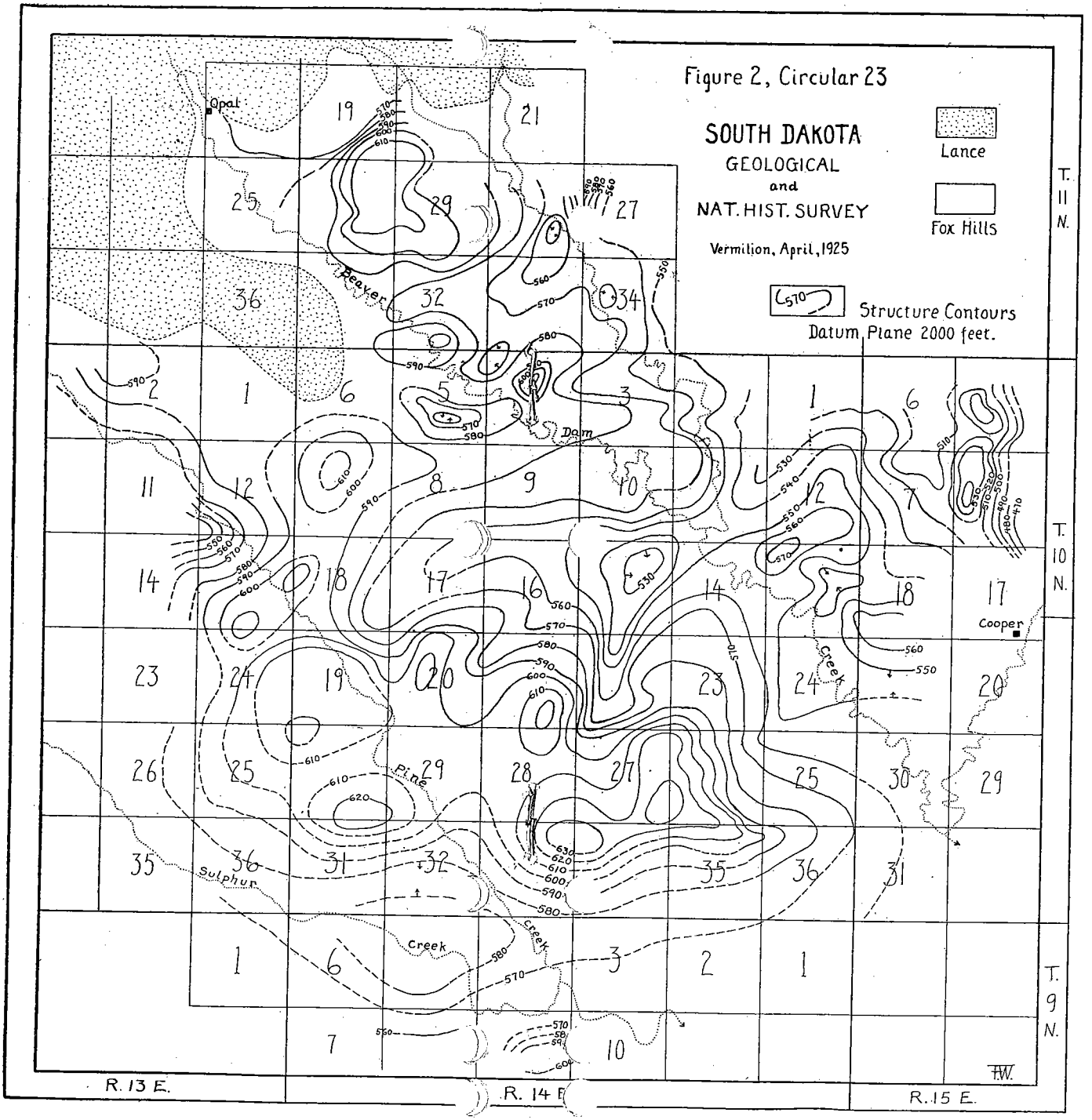
Figure 2, Circular 23
SOUTH DAKOTA
GEOLOGICAL
and
NAT. HIST. SURVEY
Vermilion, April, 1925
Lance
Fox Hills
570
Structure Contours
Datum Plane 2000 feet.
Opal
Beaver Creek
Dam
Cooper
Pine Creek
Sulphur Creek
T. 11 N.
T. 10 N.
T. 9 N.
R. 13 E.
R. 14 E.
R. 15 E.

DEPTH OF DRILLING

The following table (Fig. 3), modified from Circular 13 by the State Geological Survey, gives a generalized idea of the succession of formations with their relative thicknesses which may be encountered in drilling this area.

Cretaceous	Lance			0
	Fox Hills			250–300
	Pierre			1400
	Niobrara			250
	Carlile			300
	Greenhorn			25
	Graneros		400	225
		Mowry		25
				25
		Newcastle (Muddy)		25
				100
	Dakota			150
Comanchian	Fuson			50
	Lakota			200

Fig. 3

The depth of drilling would of course be determined by the location of the well and oil: for wells located on the domes previously described as most favorable, at least 130 to 170 feet of the Fox Hills formation would be encountered. The thickness of the formations below this would be as indicated in the table. It must be understood, however, that these thickness figures are generalized and might vary considerably in any given area. Assuming that the figures given are approximately correct, the depth to the several possible reservoir sands would be as follows: to the Niobrara, about 1,550 feet; to the Carlile, about 1,800 feet; to the Newcastle, about 2,200 feet; to the Dakota, about 2,500 feet; and to the Lakota, about 2,700 feet.

As stated by Moulton in Circular 14 of the State Geological Survey, "Oil and Gas Prospects in Southern Perkins County," it is advisable to test the formations for a considerable depth below the Lakota in so far as they may be developed under this region. This would mean drilling to a depth of 4,000 feet or more. In view of the fact that formations below the Lakota are productive in parts of Wyoming, they should be tested for in the South Dakota region, and no test for oil would be final without penetrating these formations if they are present.

SOME PRESENT VIEWS RELATIVE TO OIL POSSIBILITIES IN SOUTH DAKOTA

The field studies of the State Geological Survey during the past few seasons and the investigations of other geologists have added considerable to the information bearing upon oil possibilities in the State since the publication of Bulletin 10. On the whole, the present views of the writer relative to oil possibilities in western South Dakota are somewhat more optimistic than the views which were presented after the reconnaissance work of the field season of 1922. This is especially true of two vital factors which were considered from an unfavorable standpoint at that time—the question of possible production in low-dip structures and the potency of artesian water circulation in governing oil accumulation. These will be considered in their order of mention.

Low Dip Structures.—The outstanding reason that geologists have failed to give the Great Plains region in the past serious consideration has been the general absence of folds with the pronounced dips that characterize the productive structures in areas to the west. The discovery of oil in the Sweetgrass arch of northern Montana, which has dips as low as 5°, is a striking exception to the above general rule. Space will not permit a consideration of the various explanations offered for the general failure of low-dip structures in the Rocky Mountain fields to produce oil, but low-dip folds are not to be condemned in the light of present geologic evidence.

Although the regional dip of the strata in the plains region of South Dakota is slight, generally less than 10 feet to the mile, the writer believes that in so far as the structural factor is concerned, any folds with a closure of 70 feet are worthy of testing. This figure is given as sufficiently large to allow for errors in mapping due to possible confusion of dips produced by local or superficial causes with those of a regional order. In a region of essentially horizontal strata it is generally difficult to differentiate between true structural dips and those of local origin, and this is especially true in South Dakota where false and superficial structures are common. These features are discussed at length in Bulletin 10.

Relation of Artesian Water Circulation to Oil Accumulation.—It was indicated in Bulletin 10 that the active artesian water circulation

was probably detrimental in allowing oil or gas to gather in structural traps formed by the sandstones through which such waters were moving. The effect of artesian circulation upon possible oil accumulation involves a number of indeterminate factors such as varying porosity of sands; size and shape of folds and resulting effect upon water movement; and the relation of saline waters found in certain wells to the general artesian circulation.

The hundreds of flowing wells in the eastern part of the State indicate that the circulation is active. The fact that none of these wells has shown positive traces of oil is of interest. This would suggest that the active circulation has kept the sands washed free of oil. However, in spite of this unfavorable indication, there are certain factors in favor of possible oil accumulation in certain areas, especially the northwest part of the State, which merit serious consideration.

The presence of saline waters in some of the artesian wells suggests the possibility that locally at least the circulation is sluggish. This would allow the accumulation of oil and gas in such areas if structural traps were present. With folds of sufficient magnitude in reservoir sands it is possible that their higher parts might be relatively free of active circulation water, and hence allow the accumulation of oil and gas.

In this connection it is important to note that the relatively slight folding at the surface, as indicated on the appended structure map, may increase with depth. The thick section of soft shales which lies between the surface formations and the deeply buried sandstones considered as possible sources of oil, has probably absorbed the folding of these buried sandstones so that such folding is not reflected at the surface to the extent that it exists with depth. The core from the diamond drill hole which is being put down near Isabel has already furnished some information on this point, as it suggests an increase of dip with depth.

Further light on the accumulation of oil and gas in small domes where the reservoir rocks are more or less flooded by artesian waters is given by Moulton in Circular 14 of the State Geological Survey. A part of his discussion is also pertinent to this area and is here quoted:

"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 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."

Faulting and Oil Accumulation.—It is of interest to note that Moulton and other geologists who have worked in Rocky Mountain fields to the west, believe that faulting may be an important factor in governing the accumulation of oil in the plains region, since so many structures in the Wyoming and Montana fields especially are characterized by oil deposits associated with fault zones. The faults have acted as an aid both to migration and trapping of the oil and gas. As a result, faulted uplifts are looked upon with more favor than those which lack this structural feature.

The writer believes that the presence of faults should be given serious consideration. On the other hand, structures in western South Dakota should not be considered less favorably because of the lack of faulting. In general the faults which show at the surface over this region are generally characterized by small displacement. In some localities the displacement doubtless extends to a considerable depth, but it is important to note that the thick series of Cretaceous shales may have absorbed or altered the dislocation along the fault planes to such an extent that it would be difficult to predict what fault conditions would exist in the deeply buried zones where the reservoir sands may be present. Whether the numerous small faults which are present over this general region extend to the depth of the possible reservoir sands is thus a matter of uncertainty. Conversely, it is possible that faults which may exist in the deeply buried reservoir sands may show only slightly at the surface or not at all. Altogether, the writer believes that the element of faulting is too uncertain in this area to be used as a positive factor in condemning or approving a structure.

Relation Between Surface and Subsurface Structures.—The mapping of structural features in northwestern South Dakota from a study of outcrops is a difficult matter, owing to the general absence

of good outcrops and the widespread development of false or superficial structures. This fact has been discussed at some length in previous publications of the State Geological Survey, especially Bulletin 10.

All of the formations are characterized by slumping along their outcrops, and false dips are also produced by ancient erosional slumping in which the slump blocks have been buried under later deposits. Extreme lenticularity of bedding, especially in the Lance formation, and large-scale cross bedding further complicate structure mapping. In view of these facts structures can only be mapped by carefully recording elevations on some satisfactory key bed. Local dip readings cannot be relied upon. This naturally limits the mapping of those horizons which offer the most satisfactory key beds. The Fox Hills formation has been found most satisfactory in this respect; the Pierre formation is of value at least locally; and the Lance formation has thus far proved to be very unreliable because of the extreme irregularity and lack of uniformity in its deposits. Hence surface structures must be regarded everywhere in the area with critical caution and especially when they are used to interpret subsurface structural features.

The fact that the relation between surface and subsurface structural features is a deceptive one has already been brought out in the discussion of faulting and oil accumulation. As mentioned in Bulletin 10,—and this fact has been further sustained by later studies,—folds of some magnitude in depth may not be so conspicuous at the surface, owing to the tendency of the soft Cretaceous shales to absorb the stresses when transmitted upward. This opens up the possibility of structures with small closure at the surface, developing into more conspicuous folds with depth.

The possibility that a pre-Cambrian granite ridge extends between the Black Hills uplift and the Sioux quartzite region of eastern South Dakota is another factor meriting consideration, in view of the effect of such a buried ridge upon the development of favorable structural conditions in the overlying formations.

The presence of such a buried ridge would also favor the development of sand horizons in the upper Cretaceous shales in the areas where they approach it, if the ridge were an island during upper Cretaceous times. This would, of course, mean the development of possible reservoir horizons in this thick series of marine shales, which over much of the State seem to be largely barren of important sandstone members.