South Dakota
Geological and Natural History Survey
Freeman Ward, State Geologist

CIRCULAR 22

Structures
in
Northern Haakon 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.

LOCATION

The area concerning which this report is written is in northern Haakon County in what is called the Plum Creek region. Plum Creek (on some maps Snake Creek) runs north through the region, joining the Cheyenne River just below the mouth of Cherry Creek, which comes in from the opposite direction. The region has been variously referred to as Cherry Creek, Leslie, Plum Creek, Snake Creek, West Fork, Hudson, Midland, Philip. The proper terminology is Plum Creek.

West Fork Post Office is in the north part of the tract: it is 52 miles from Midland and 42 miles from Philip. Milesville, in the western part, is 10 miles nearer Philip.

The area closely investigated includes part or all of T. 5-7 N., R. 21-22 E. Much of the adjoining country was also given a brief examination. The index map (Fig. 1) shows the location of this area as well as other areas already examined in detail by the State Survay.

ACKNOWLEDGMENTS

It was through the efforts of Mr. John Schoof, of Gettysburg, and Mr. Daniel Bierwagen, of West Fork, that so much was accomplished. They saw to it that the Survey party was provided with

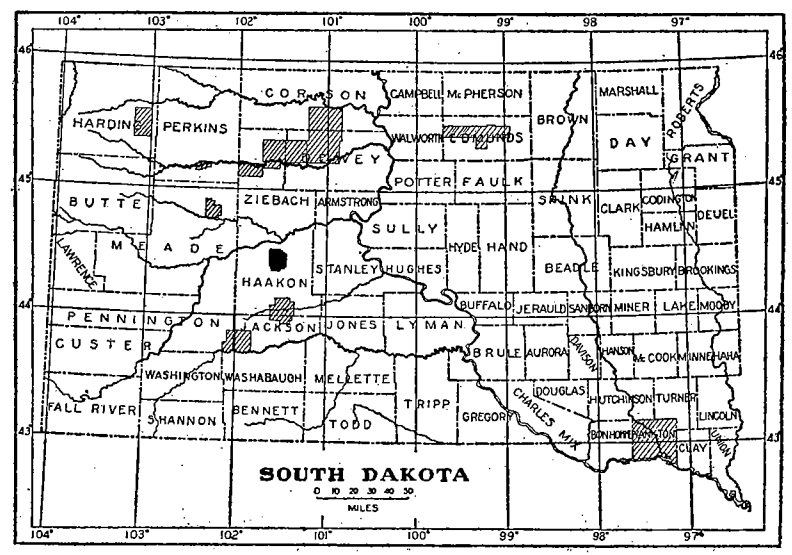

Fig. 1. Index Map

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

transportation and subsistence. Without this help the Survey could not have spent time in the region at this time to make a detailed investigation. The writer is indebted to Dr. T. W. Stanton, of the U. S. Geological Survey, for the determination of the fossils. Theodore Wolter served as instrument man.

PURPOSE

The study of the structure was undertaken because of its relation to the oil problems of the State.

The discussion of the oil possibilities of the State will not be taken up in this report. This matter is treated in several of the publications already issued by the Survey, to which the reader is referred. But one of the pressing needs in the solution of this important problem is information concerning the deeper formations of the State. This means that drilling will have to be done. And drilling should be undertaken only on approved structures. The location of "structures," then, becomes a necessary preliminary part of the program.

In this connection one should review the fact, now well established by several seasons' work, that real deformation can only be successfully worked out in this plains region by the use of key beds. Dip readings have proved to be inadequate. This matter becomes more significant when it is known that the Pierre shale is the only formation visible in the area. And the Pierre shale is notably deficient in workable key beds. Last year the Survey worked a Pierre area in southern Haakon County and could make no headway. (See Circular 17.)

Part of the investigation was undertaken, then, to see if another area of Pierre shale would yield anything more satisfactory in the way of key beds. It is with great pleasure that we record the presence of a reliable, usable key bed.

FIELD METHODS

After preliminary work had determined the presence of a usable key bed, the plane table was employed to do the mapping in detail. A telescopic alidade was used and all measurements were made by stadia. Mapping was done on a scale of two inches to the mile. Later, part of the adjoining territory was examined rapidly, elevations being determined by barometer. Something over six weeks' time was spent on the work.

TOPOGRAPHY

Away from the creek the region consists of a high prairie flat at an approximate elevation of 2,300 feet. This has a true plains topography with very little relief.

Plum Creek with its tributaries has cut deeply below this prairie level, producing a very rough topography with a relief of 100 to 200 feet over a tract three to six miles wide all along the creek. Throughout much of the creek basin there is a high bench about 100 feet below the prairie flat. Some of this extends for several miles and joins the prairie flat by a gentle slope. Much of it consists of narrower areas along the divides between the tributaries. There are a few smaller, detached bench remnants. The total relief in this area is approximately 300 feet.

There have been three major cycles of erosion in the area; one marked by the high prairie flat, another by the high bench, while the third is the valley cycle, which is a composite.

As would be expected, travel is easy and the roads good on the prairie flat and high bench. But very few roads and all of them steep reach from these flatter areas to the creek basin. There is a well developed flood plain along Plum Creek but the creek meanders excessively in a well marked trench. And there is only one bridge along 20 miles of the creek. The natural highway is up and down the creek but the way is continually interrupted by bad creek crossings, impassable when the creek runs, and difficult at any time.

As a result automobile travel is very much restricted, which means that much time must be consumed on foot in getting to all parts of the area, as is necessary in detailed mapping.

Plum Creek is an intermittent stream, flowing only during the rainy seasons. Many pools persist even during the drier part of the year.

FORMATIONS

The only formations in the area are the Pleistocene and Pierre (Cretaceous).

PIERRE SHALE

Since the matter of key beds in the Pierre is so important the section seen (a total of about 225 feet) is given in considerable detail. There are two main divisions and several subdivisions of the Pierre. These will be described from the top down. Several local terms (indicated by quotation marks) are retained in the description. They had been applied by Mr. Bierwagen, who has given much study to the geology of the region.

"Chalky" Shale.—There is no true chalk in this group. The term "chalky" has been applied because of the presence through parts of the shale of thin streaks, spots, or a dust of a whitish secondary substance consisting of a mixture of $CaSO_4.2H_2O$, $FeSO_4$ and $CaCO_3$. Where plentiful this material makes the shale appear as if ashes were mixed with it. A measured section is as follows:—

Light colored shale, drab to light tan	8 ft.
Light yellow brown, fine sandy shale, (the sand is very fine, rather silty)	1 ft.
Yellow brown shale, few blackish streaks	15 ft.
Yellow brown shale, with "chalky" characteristics	6 ft.
Black shale with brownish streaks	3 ft.
Yellow brown shale, typical "chalky"	15 ft. (Bed K)

Since this member is the uppermost part of the Pierre of the region and so more readily subject to erosion, a large number of the outcrops have only the lowest stratum (Bed K) of the above section. This bed yields a heavy soil with a deep yellow brown color. In such case the "chalky" portions can be seen only by digging. When the exposure is very fresh the shale is a dark, slate blue (typical Pierre) color but still retains its "chalky" markings.

The bottom is often marked by the presence of a thin line of yellow to bright yellow material ($FeSO_4$), with sprinklings of sparkling, small gypsum crystals and sometimes scattering flat, bone-shaped, limy concretions. Occasionally near the bottom part is a thin band of harder, iron stained slabby shale, at times soft.

The "chalky" shale as a whole is characterized by an absence of lime concretions. But in some localities there is a narrow zone of flatter limy concretions, which weather to a bleached gray color: where these occur there is apt to be a thin (½ in.) bed of fibrous calcite about 10 feet below it. This concretion zone is approximately 70 feet above Bed Y described below.

Topographically Bed K has a tendency to be a cliff maker. There is seldom a well marked cliff but at least this material stands up better than the typical Pierre shale below.

Typical Pierre Shale.—By this term is meant the regulation thin bedded, heavy textured shale which, when fresh or nearly so, has the dark slate blue color so characteristic of the Pierre shale all over this state. On weathering the shale here is less characteristic in that it develops a bleached gray appearance so light in color that one is inclined to think of it as somewhat glary, at least on a bright sunny day. Less weathering produces a drab or light khaki effect. At a distance the weathered bare slopes have a gray rather than a somber tone. This is quite in contrast to the dark, freshly cut banks adjoining the creek.

There are present in the shale many zones of blue gray concretions composed of impure calcium carbonate and usually rather solid and tough. Some of these are definite and persistent enough to become key beds. They therefore deserve more detailed description.

"Yellow Lime."—Bed Y.—This is an impure lime carbonate, for the most part less pure than the others. As a consequence the usual blue gray color is somewhat paler, though this cannot be used alone as a means of identification. It is commonly partly or completely enclosed by a slabby sandy member in which the sand is very fine. It frequently has a thin layer of cone-in-cone directly above it. Individual concretions are 10 to 15 inches thick and 3 to 15 feet long. They are thus larger than most of the concretions. The bed must not be thought of as being continuous. The concretions occur at a uniform horizon but are separated rather than connected, i. e., the bed is a series of unevenly spaced lenses.

On weathering, Bed Y becomes more distinctive. It changes to a light yellow brown color, commonly a faded khaki tint: it may

become darker but never has a rich yellow brown color like that developed in the "chalky" bed; rarely it is rusty looking. Weathering also causes it to break up into small, blocky fragments one to three inches in diameter: the fine sand member becomes slabby at the same time. It is rarely fossiliferous. There are some variations besides the color variation above mentioned. At times the sandy member is practically absent. Locally, though rarely, it is fossiliferous. In one locality it had associated with it gray, coarse, shot-like concretions within the larger mass. Cracks filled with calcite is a condition that may be found.

Bed Y is about 30 feet below the base of Bed K.

"Baculite" Bed.—Bed X.—This horizon contains concretions which weather with a peculiar chipped outer surface having the appearance of a partly formed eolith. Baculites occur in them frequently enough to give the name to the bed, but are not uniformly present. Other fossils are also present. The color produced by weathering is a light gray.

Right near this bed is one equally characteristic. It consists of thin, harder, slabby shale which weathers to a yellow brown color with an orange to rusty tint. It is commonly fossiliferous.

Bed X is 25 to 30 feet below Bed Y.

Lower Portion of the Pierre.—The lower portion of the Pierre exposed in this region consists of the ordinary dark slate blue shale with scattering concretions. These latter occurred at many horizons, were not very persistent, and had no distinctive fossils or other diagnostic character.

A few other concretion horizons should be mentioned. One occurred 5 to 10 feet above Bed Y very frequently but not continually. It consists of as pure lime carbonate as any concretion seen. When fresh it is blue gray in color; it weathers to a light gray. It is practically always fossiliferous. Very often it is cracked and the cracks are filled with calcite.

Several concretion zones are associated with cone-in-cone material. The most persistent of these beds is 5 or 10 feet below Bed Y, though it is not always present.

Key Beds.—The most persistent key bed is Bed Y. Since it consists of separated small lenses it cannot be found continuously. It can be found on at least every other spur unless wash or sod have gained too great a headway. In a small way it is a bench maker and so will be found more often on spurs than in valleys; indeed, the valleys may have developed largely because the concretion lenses were less abundant at these points. It should be looked for on weathered slopes where there is a wide band of bleached gray or light color.

Since Bed K is the topmost member, in many cases it has been removed by erosion. If erosion has not cut deeply, this bed is practically always present. It should show up more often as a

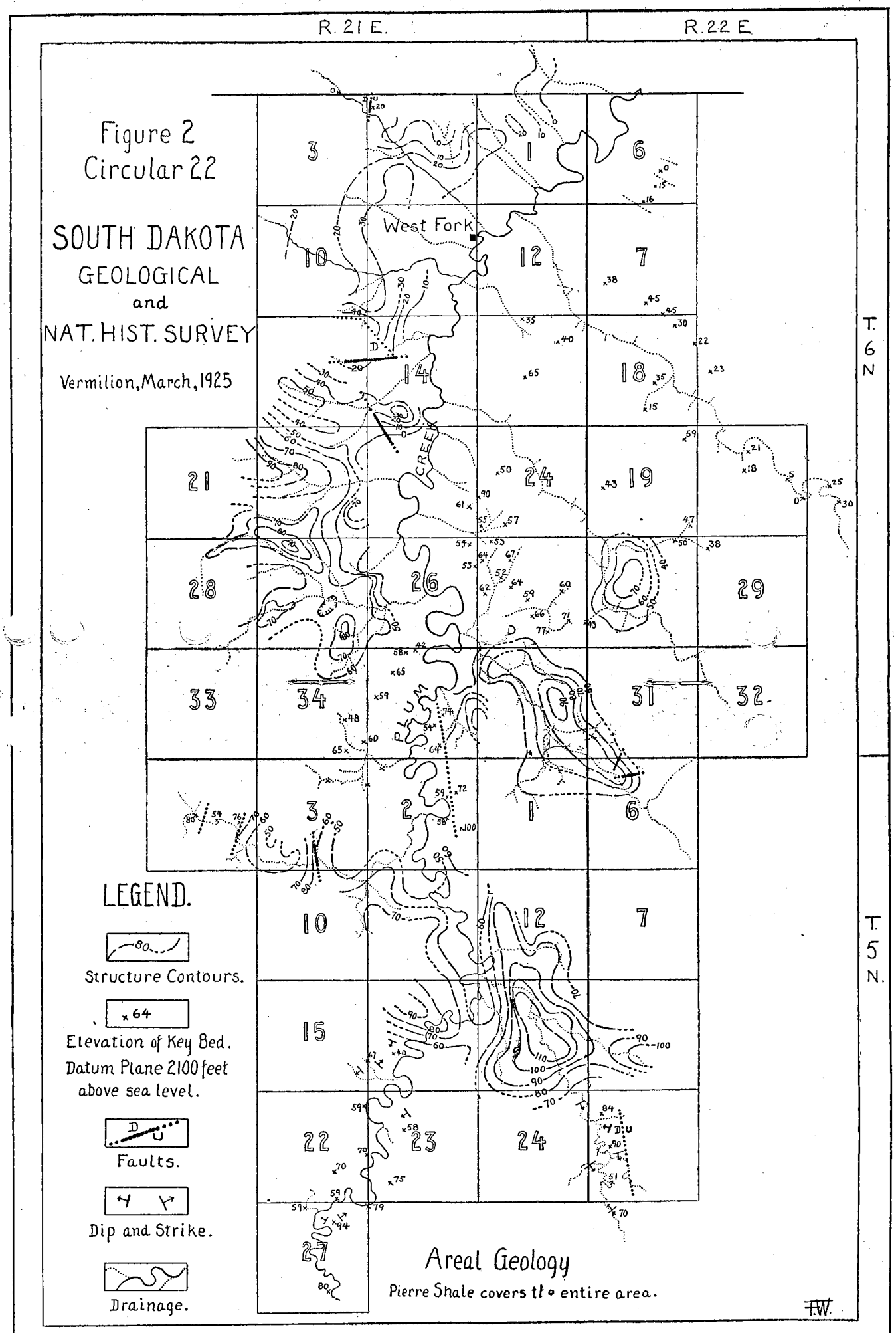
R. 21 E.
R. 22 E.
T. 6 N.
T. 5 N.
Figure 2
Circular 22
SOUTH DAKOTA
GEOLOGICAL
and
NAT. HIST. SURVEY
Vermilion, March, 1925
West Fork
PLUM CREEK
LEGEND.
Structure Contours.
Elevation of Key Bed.
Datum Plane 2100 feet
above sea level.
Faults.
Dip and Strike.
Drainage.
Areal Geology
Pierre Shale covers the entire area.
F.W.

Fig. 2

darker yellow brown zone above the lighter zone previously mentioned because it yields a dark, rich yellow brown heavy soil. Digging into this soil may reveal "chalky" flakes. Where too steep for soil accumulation it may show as a whitish, streaked, or ashy looking band.

Bed X is present fully 50 per cent of the time in its proper position below Bed Y. Since it is quite thin it may easily be obscured by even small amounts of wash. Of course in many instances where Bed Y occurs near heads of small valleys or draws erosion has not cut deeply enough to reveal Bed X.

Age of Pierre.—Since the Pierre is probably 1,300 feet thick and only about 225 feet of it is exposed in this area, it becomes important to determine what part of the formation is exposed. A suite of representative fossils was submitted to T. W. Stanton of the U. S. Geological Survey. He reports unqualifiedly that they indicate the upper Pierre.

The list of fossils is given below: they were all collected from a fifty foot zone whose upper limit is about 15 feet above Bed Y.

Inoceramus (*Actinoceramus*) *fibrosus* (Meek and Hayden)
Inoceramus sagensis Owen
Yoldia evansi Meek and Hayden
Yoldia scitula Meek and Hayden
Baculites compressus Say
Baculites ovatus Say
Baculites grandis Hall and Meek
Nuculana bisulcata Meek and Hayden ?
Limopsis parvula Meek and Hayden
Fasciolaria (*Piestochilus*) sp.
Scaphites nicolleti (Morton)
Scaphites conradi (Morton) ?
Scaphites conradi var. *intermedius* Meek
Haminea occidentalis Meek and Hayden ?

PLEISTOCENE

Under this heading is included the sands and gravels capping the prairie flat, below which the valley of Plum Creek is cut, and the high bench developed within the valley. According to well records this formation is 10 to 40 feet thick.

One striking thing about these sands and gravels is that they cover the prairie along the divides for several tens of miles and are in places several miles wide. Other striking characteristics are the poor sorting, the large proportion of sub-angular fragments, and the many varieties of rock material represented. In the course of an hour's search one would be able to find twenty different rock and mineral species. Some of these have undoubtedly been derived from the Black Hills.

The sands and gravels on the prairie flats are undoubtedly related to other similar high level gravels and sands found in many

widely separated parts of western South Dakota. They are tied up with the very early erosional history of the State, possibly involving glacial action. The sands and gravels on the high benches were probably deposited during a later cycle and represent reworked material moved but a short distance from the original adjoining higher deposits.

The presence of this porous and permeable medium resting on impermeable shale has made possible the many springs and generally good well water found in the region. This deposit also accounts for the usual productiveness of the farms on the prairie flats.

STRUCTURE

All the work of the Survey has established the fact that there are no high dips or steep folds in the plains strata of the State. It has also been found that the structure cannot be worked out by taking dips and strikes with a clinometer. Slumping is extremely common. Other superficial structures weave in and out enough to make a great variety of dips which have no apparent relation to the true deformation. The area in question possesses these same characteristics. Structures were therefore worked out by the use of the key beds already described. The few dips and strikes plotted were determined by running elevations on key beds.

The structure of this area is best described by the term undulatory. This means there are many small folds, the largest a mile or two long. A northwest-southeast or a northeast-southwest trend to the folds is apparent but it is not strongly marked.

Several closed structures were located. The closure was small, the maximum being 35 feet. The best of these is in sections 12 and 13, T. 5., R. 21. A second one, nearly as good, is chiefly in section 36, T. 6., R. 21. Other less prominent ones are in section 30, T. 6., R. 22., N. W. part of section 27, T. 6., R. 21., S. E. part of section 27, T. 6., R. 21. A number of structural highs were found but not enough evidence was at hand to determine whether a closed structure existed or not. These structural highs and what may be called incomplete closures are plainly marked on the map. The structure contours are drawn on the key bed (Bed Y). The figures give the elevation of this same bed at the place indicated.

Several small faults are present. These are usually short in length and all seem to be of the normal variety. The maximum throw observed was 40 feet. There are a number of pseudo faults in the area: they are the result of slumping. A great deal of care was taken to eliminate the abundant slumping from the interpretation of true structure.

Reference to the map (Fig. 2) will aid in understanding the location, size, etc., of these structural features.

An additional structural feature of larger dimensions gives a background for the consideration of the possible value of the smaller ones already mentioned. A partial examination of Haakon and ad-

joining counties strongly suggests the presence of a large arch perhaps 75 by 50 miles in size.

Our conceptions of the larger structural features of the State have for years been based on Darton's work.* Bull. 10 of our Survey also has a structural map based on Darton. In all three of these maps the structure of the western part of the State is expressed by contours drawn on the Dakota sandstone.

It is believed that for a large portion of this western area such maps are based altogether too much on assumed rather than proved evidence. In the region between the state line on the north and White River on the south, and between the Missouri River and the Black Hills, there is a continuous tract approximately 140 by 120 miles, involving some 17,000 square miles, in which there is not a single well to the Dakota. Nor can it be safe to assume that the thicknesses of the formations above the Dakota are uniform throughout this large area. In this connection one should note that a recent hole has proved the Pierre to be 300 feet thicker than was estimated.

It becomes necessary, then, to determine the thickness of the overlying formations more accurately or choose a more available reference horizon, or both. For the present an attempt is being made

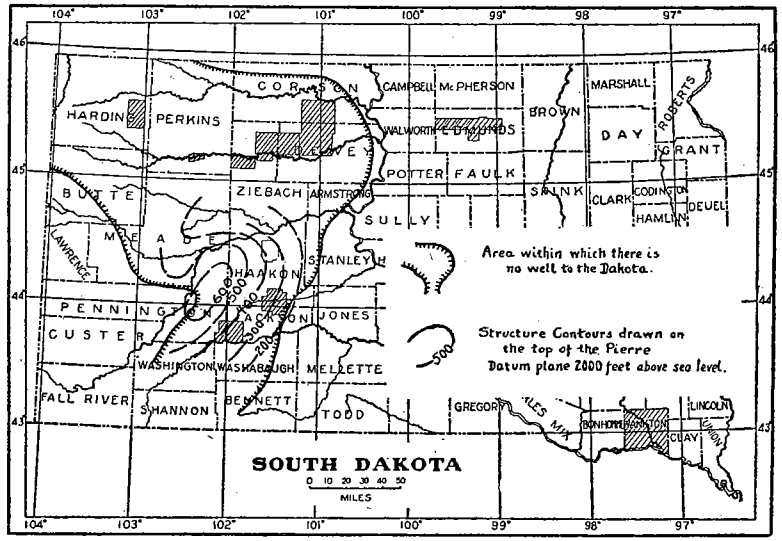

Fig. 3

to use the top of the Pierre as a horizon on which to draw structural contours. While this procedure has its drawbacks it has the one great advantage of accessibility. The map (Fig. 3) shows the result

*N. H. Darton—The Geology and Water Resources of South Dakota: U.S.G.S., W.-S.P. 227, 1909, Pl. XIII.
N. H. Darton—The Structure of Parts of the Central Great Plains: U.S.G.S., Bull. 691 A, 1918, Pls. I, III.

of this newer interpretation. This map no doubt has many errors in it. But it is believed that a dozen approximate figures on the elevation of the top of the Pierre are of more value than practically no observations on the Dakota.

OIL POSSIBILITIES

General Statement.—No attempt will be made to discuss at any great length the oil possibilities for the State as a whole. The several publications already issued by the Survey have treated this matter rather fully, notably Bulletin 10 and Circular 20.

In general, it can be said that the Survey expects oil in commercial quantities to be found somewhere in the western part of the State. The reasons for this belief are several, as follows: Real deformation has occurred in these supposedly flat plains strata; folds and closed structures have already been located in several parts of the State. There is a thick series of sedimentary rocks present. In this series, as far as they can been seen in the adjoining, better known areas, there are possible source, reservoir and cap rocks. A few real showings of oil have been reported. There is still a high degree of uncertainty because the exact condition of the deeper formations is not known. Drilling is absolutely necessary to settle this part of the problem.

As far as this area is concerned, closed structures have been located. These in themselves have too small a closure to make them worth drilling at present. But it is believed that their value is greatly increased because they are superimposed upon the larger arch. Hence they are considered worthy of a test. Shallow drilling in the northern edge of this area proved the presence of gas coming from sandy beds in the Pierre and Carlile.

The formations present and their thicknesses are indicated in the accompanying table (Fig. 4). The Pierre is the only formation

Pierre— Bed Y to bottom	1,100
Niobrara	250
Carlile	300
Greenhorn	25
Graneros	300–500
Dakota-Lakota	400–600
Lower Formations	Unknown

Fig. 4

exposed in the area or anywhere near it. The shallow drilling in T. 7., R. 22, immediately adjoining the area on the north showed the Niobrara and upper part of the Carlile to be present. The statements concerning the formations and their thicknesses from the Carlile down are at the best only estimates. The nearest deep well is that at Standing Butte, about 35 miles to the northeast.

No sands or sandstones of any consequence are to be expected in the remaining part of the Pierre.

A thin sand was encountered in the above mentioned shallow drilling, 10 to 60 feet below the bottom of the Niobrara, a thicker one (20 ft.) was struck 165 feet below the bottom of the Niobrara. Both contained gas. It is possible that another sand will be found nearer the bottom of the Carlile.

The record of the Standing Butte well suggests that, after the Graneros is penetrated some distance and from there on through the Dakota-Lakota series, several sandstones may be expected. At least one and maybe all will bear artesian water.

Depth of Drilling.—If drilling were started along the creek in section 13, T. 5., R. 21, there would be about 1,050 feet of Pierre to penetrate. This would make the depth to the top of the Carlile 1,300 feet, and to the Dakota 1,925 to 2,125. Drilling depths in other localities may be calculated by considering that the key bed Y is 1,100 feet above the base of the Pierre.

Cost of Drilling.—The statements made by Russell in Circular 20 apply so well to this area that they are repeated here:—

"The cost of drilling oil wells varies not only with the depth, but with the location, distance from railroads, and drilling water, presence of water sands which must be cased off, hardness of formations and amount of caving. The formations are nearly all very soft, and the actual drilling would not be an expensive proposition. As, however, most of the Pierre, part of the Carlile and probably part of the Graneros consist of very soft, cavy shale, which becomes a plastic mud when in contact with water, it would be necessary to follow the drill closely by casing, and consequently a considerable amount of casing would be needed. This would presumably be the chief item in the cost of the well.

"Three methods of drilling might be used—the cable tool, rotary and diamond drill. It appears to the writer that the best one for wild-catting in the area under consideration is the diamond drill. The diamond drill is much cheaper than the other two, and gives a much better idea of the formations, which is highly valuable whether oil is encountered or not. If necessary the diamond drill hole may be bailed down and the flow of oil tested. The cost of drilling a 3,300 foot diamond drill hole would probably be in the neighborhood of $30,000, possibly only $25,000. If rotaries were used, the cost would probably be considerably more, while cable should be the most expensive, owing to the cavy formations.

"The writer is indebted to Mr. J. S. Mitchell of the Sullivan Machinery Company for information on the diamond drill."

SUMMARY

(1) Several closed structures and structural highs have been located. Their closure is moderate but their superposition upon a large arch gives them added value.

(2) General conditions as to source, reservoir, and cap rocks are probably favorable. But it must be remembered that the condition of the deeper formations is very uncertain.

(3) The depth of drilling is much less than on any approved structure so far located in western South Dakota.

(4) The distance from the railroad and the rough topography along Plum Creek will make the bringing in of heavy machinery a difficulty. Water for drilling will be a serious problem.