THE STRUCTURE OF PARTS OF THE CENTRAL GREAT PLAINS.

By N. H. Darton.

INTRODUCTION.

In the study of the geology of different parts of the central Great Plains many data have been accumulated that throw considerable light on the underground structure of the rocks. Most of the features observed have been described in previous publications,[1] but others are set forth here for the first time. The area treated is shown on Plate I, on which the general structure is represented by contour lines. It is believed that a presentation of all available facts as to structural conditions in this region is warranted by the prevailing great interest in the possibility of the occurrence of petroleum and gas. Except near Florence and Boulder, Colo., and in Kansas from Eldorado to Eureka and eastward no traces of oil have been found in the central Great Plains region. As will be shown in this report, favorable structural features, such as domes and anticlines, occur at many places in this region; and while there is no evidence that the strata contain oil or gas in commercial pools these folds are more favorable for the location of tests than the basins or the monoclines. Only the drill can determine whether or not oil is present.

The region is underlain by a thick succession of Cretaceous, Carboniferous, and older strata, including beds that in other regions yield oil or gas. Many holes have been sunk at intervals in the past, most of them to obtain water from the Dakota sandstone. Others have penetrated the upper part of the underlying "Red Beds," but except in places in central Kansas they have not tested the lower strata. Until the underground conditions are ascertained

[1] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, 433 pp., 72 pls., 1905; Geology and underground waters of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Prof. Paper 52, 90 pp., 28 pls., 1906; Geology and underground waters of South Dakota: U. S. Geol. Survey Water-Supply Paper 227, 156 pp., 15 pls., 1909.

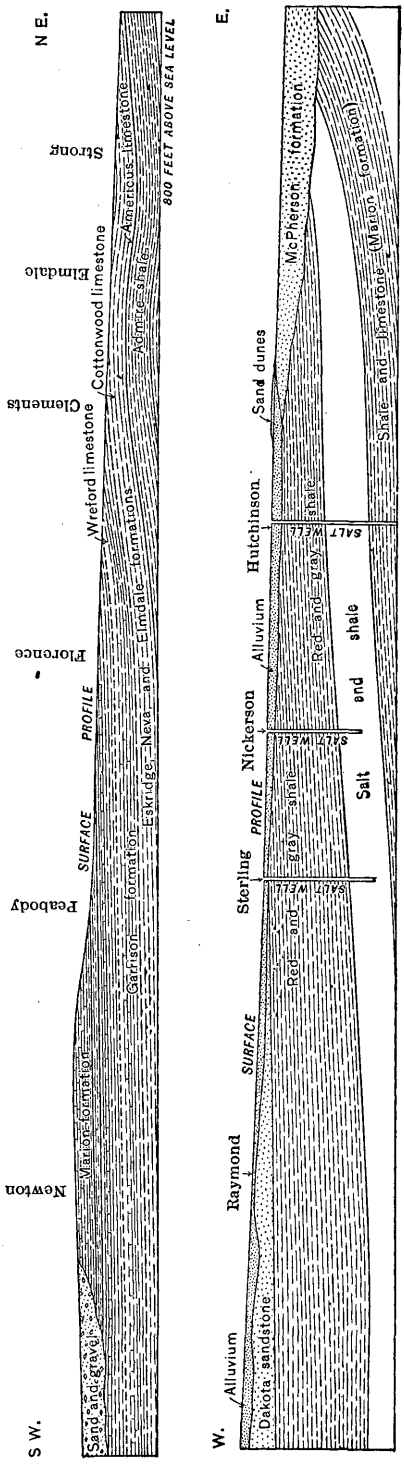

FIGURE 1.—Sections showing underground relations of rocks along Atchison, Topeka & Santa Fe Railway between Strong and Ellinwood, Kans.

no boring can be regarded as a complete test in this region unless it penetrates all the older limestones and associated beds to the granite or schist basement. Moreover, most of the borings so far made have not been located in anticlines or domes favorable for oil or gas accumulation.

KANSAS.

CENTRAL KANSAS.

Very few facts are available as to the structure of the portion of Kansas lying between the ninety-sixth and one-hundredth meridians. The district is underlain by a thick succession of shales and limestones of Carboniferous age, above which to the west are sandstones and shales of Cretaceous age. The surface limit of the Cretaceous beds is shown approximately by a line on the map (Pl. I). In the area in which the older rocks are exposed there is a general very low dip to the west, with local variations from place to place. The Cretaceous rocks dip in various directions, sloping into a wide, shallow syncline whose center is in the western part of Smith County and rising into a low dome whose axis passes near Dodge and Jetmore. Some of the general features in the central part of the area are shown in the sections (fig. 1).

The only district in which details of structure have been determined is about Cottonwood Falls and in adjacent

LEGEND

Contour lines show structure of the Dakota sandstone by indicating the altitude of its top above or below sea level

(Contour interval 100 feet; broken lines hypothetical)

Area covered by sand, grit, clay, and limestone of late Tertiary age

(150 to 200 feet thick in most places)

Area in which Dakota and associated sandstones are absent, and underlying granite or quartzite, which do not yield oil or gas, are at or close to the surface

Area in which Dakota and associated sandstones are absent, and underlying shale and limestones or "Red Beds" constitute the surface

Margin of Dakota sandstone

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PRELIMINARY MAP OF THE CENTRAL GREAT PLAINS, SHOWING THE STRUCTURE OF THE DAKOTA SANDSTONE

BY N. H. DARTON

Scale 1/2,500,000

APPROXIMATELY 40 MILES TO 1 INCH

25 0 25 50 75 100 MILES

25 0 25 50 75 100 KILOMETERS

portions of Chase, Marion, and Butler counties, lying within the Cottonwood quadrangle. The mapping by Prosser and Beede[1] brings out the fact that in this district the general westward-dipping monocline of Permian limestone and shales bears two notable domes. One of these centering 2 or 3 miles southeast of Elmdale lifts the strata about 200 feet in an area 9 miles wide from east to west and 12 miles long from north to south. In places the dips are as much as 3° or 4°. In the southeast corner of Marion County is the Burns dome, which is about 200 feet high and affects a smaller area than the Elmdale dome.

The Elmdale dome yields considerable gas, mostly from holes about 200 to 600 feet deep, and the product has been piped to portions of the surrounding country.

Deep holes have been sunk at many places in central Kansas for water, salt, and oil, but oil has been found in promising amount only in the vicinity of Eldorado, Augusta, Dexter, and Eureka, and gas only about Elmdale, Arkansas City, and Winfield. Large amounts of oil and gas are obtained farther east in Kansas. A list of the deeper holes is given in the following table, but it does not include all holes bored during the last few years.

Deep borings in Kansas, longitude 96°–100°, mostly prior to 1902.

Locality.	Depth (feet).	Results.
Barton County:		
Great Bend	1,365	Flow of salt water from Dakota sandstone at 344 feet.
Butler County:		
Eldorado	Deep.	Salt water.
Rosalia, near	2,060	Salt water and fresh water.
Chase County:		
Cottonwood Falls	1,980	
Cottonwood Falls, 8 miles northwest of.	2,500	
Elmdale	3,200	No results; hard rock, 1,707–3,200 feet.
Strong City, 1½ miles west of	1,916	Gas at 339–349 feet; water; no oil.
Cloud County:		
Asheville	638	Salt water.
Cowley County:		
Winfield	1,200–3,100	Do.
Dickinson County:		
Abilene	1,260	Mineral water.
Elk County:		
Howard	1,410	No result.
Geary County:		
Alta Vista, 4 miles northwest of	2,760	To granite.
Junction City, 3 miles west of	1,930	Flows of water; "show of oil."
Junction City, 3½ miles southwest of	1,365	Salt water at 950 feet.
Junction City, 10 miles southeast of.	1,500	
Greenwood County:		
Eureka	1,255	Brine at 499 feet.
Fall River	1,480	Brine at 972 feet.
Madison	1,986½	For gas; unsuccessful.
Harper County:		
Anthony	2,335	
Harvey County:		
Newton	1,076	
Hodgeman County:		
Jetmore	1,000	No result.
Kingman County:		
Kingman, 1½ miles north of	1,410	Salt.
Rago	1,000	Salt at 175 feet.

[1] Prosser, C. S., and Beede, J. W., U. S. Geol. Survey Geol. Atlas, Cottonwood Falls folio (No. 109), 1904.

Deep borings in Kansas, longitude 96°–100°, mostly prior to 1902—Continued.

Locality.	Depth (feet).	Results.
Lyon County:		
Admire, 3 miles northeast of	1,450	Granite at 1,360–1,450 feet.
Emporia	2,005	For gas; failure.
Marion County:		
Marion, 4 miles southeast of	2,700	For oil; failure.
Burns, 3 miles southeast of	2,500	Granite at 2,326–2,500 feet.
Burns, 10 miles southeast of	2,750	For oil; failure.
Burns, 1 mile east of	3,113	Do.
Marshall County:		
Marysville	1,360	Water.
Marysville, near	1,100	
McPherson County:		
McPherson, 3 miles west of	2,225	
Morris County:		
Kelso, near	2,552	Granite at 2,513–2,552 feet.
Council Grove, 15 miles southwest of.	2,608	Granite at 2,500–2,608 feet.
Council Grove, 7 miles south of	2,150	For oil; failure.
Nemaha County:		
Seneca	800	Granite at 600 feet.
Pottawatomie County:		
Louisville	1,100	
Wamego, 4 miles west of	895	Salt water at 427 feet; " shows of oil" at 646, 699, and 865 feet.
St. Marys	1,892	Salt water at 1,123 feet.
Onaga	602	Gas and flowing water.
Onaga, near	1,734	Granite at 1,035–1,734 feet.
Broderick	1,100	
Pratt County:		
Pratt	800+	Salt at 600–800 feet.
Reno County:		
Hutchinson, south of	1,307	Salt.
Hutchinson, about	800+	Several salt wells.
Arlington	1,000	Salt.
Rice County:		
Lyons	1,625	Salt well.
Sterling	980	Do.
Little River	964	Brine.
Riley County:		
Zeandale	1,200	Granite and schist at 958 feet.
Sedgwick County:		
Wichita	1,605	Salt water at 1,300 feet.
Wabaunsee County:		
Alma	1,912	Salt water and gas.
McFarland	2,006	
Wellington	1,000	No result.
Wabaunsee, 3 miles south of	2,000	Granite at 1,170–2,000 feet.
Wabaunsee, 2 miles west of	1,200	Granite at 945–1,200 feet.
Washington County:		
Washington	2,200	Do.

It has been found that granite and other similar crystalline rocks constitute a ridge projecting up into the limestones and cutting off the lower sedimentary members in part of central Kansas. This rock was found at Zeandale, 8 miles west of Manhattan, near Elmdale, west of Cottonwood Springs, and near Wabaunsee, Council Grove, Onaga, Kelso, Admire, Alta Vista, and Burns. Near Zeandale a 1,093-foot hole was in this rock from 958 feet to the bottom, and another hole 1,200 feet deep a mile east penetrated granite 255 feet. Two Elmdale borings struck the rock at 1,707 feet, and it continued to a reported depth of 3,100 feet. The crystalline rocks have also been reached in wells at many other places in a narrow zone extending through Nemaha, Pottawatomie, Wabaunsee, Morris, and Chase counties and the northern part of Butler County. The northward extension of this ridge is indicated by the occurrence of crystalline rock at a depth of 552 to 612 feet in a hole sunk in 1904 some distance

south of Pawnee City, Nebr.,[1] where it projects high into Pennsylvanian strata and doubtless was the source of the granite boulders in the Pennsylvanian outcrops in Kansas.[2]

Its course is coincident, or nearly so, with an anticline having steep dips along its east side and extending far north-northeast from the Eldorado dome. In that dome, however, it lies very deep, for a 3,600-foot hole failed to reach it. It rises rapidly toward the north, and near Burns and farther north it cuts off the oil-bearing strata. Many facts regarding this feature have been recorded by Wright,[3] Powers,[4] and Taylor.[5] Haworth[6] has reviewed some of the evidence presented in this connection and given data relating to several wells.

SOUTHWESTERN KANSAS.

The Cretaceous strata in southwestern Kansas rise on the slope of a gentle dome that culminates in southeastern Colorado. The Dakota sandstone and the overlying shales and limestones crop out in parts of the valleys and are overlain by Tertiary sand, gravel, and grit on the uplands. Below the sandstone are red shales which appear in the deeper part of the Cimarron Valley and are reached by deep borings in the region to the north. The sections given in figures 2 and 3 show some of the general structural features.

Two smaller domes on the general monoclinal slope mentioned above may afford structural conditions favorable for the occurrence of oil or gas. One of them is at Dodge, where the relations are not well exposed; the other is southwest of Syracuse, where the scattered outcrops and well records indicate doming of considerable steepness. The configuration of this dome is shown in figure 4. The Dakota sandstone crops out on the southeast slope of the dome and is reached by wells at other places, so that its position is indicated by ample data. Additional evidence is furnished by the relations of outcrops of the Graneros shale and Greenhorn limestone on the slopes of the dome.

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[1] Russell, F. W., A crystalline rock near the surface in Pawnee County, Nebr.: Am. Geologist, vol. 1, pp. 130–131. Darton, N. H., Preliminary report on the geology and underground-water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, p. 284, 1905.

[2] Twenhofel, W. H., Granite boulders in the Pennsylvanian strata of Kansas: Am. Jour. Sci., 4th ser., vol. 43, pp. 363–380, 1917.

[3] Wright, Park, Granite in Kansas wells: Am. Inst. Min. Eng. Bull. 128, pp. 1113–1120, 1917.

[4] Powers, Sidney, Granites in Kansas: Am. Jour. Sci., 4th ser., vol. 44, pp. 146–150, 1917.

[5] Taylor, C. H., The granites of Kansas: Southwestern Assoc. Petroleum Geologists Bull., 1917, pp. 111–125.

[6] Haworth, Erasmus, On crystalline rocks in Kansas: Kansas Univ. Geol. Survey Bull. 2, 33 pp., map, plates, 1915.

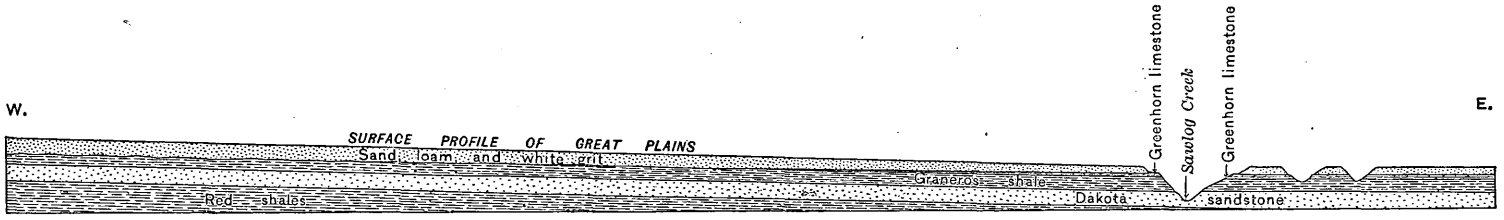


FIGURE 2.—Section showing underground relations of rocks in plateau north of Arkansas River between Spearville and Mansfield, Kans. Vertical scale exaggerated, increasing apparent tilt of the beds.

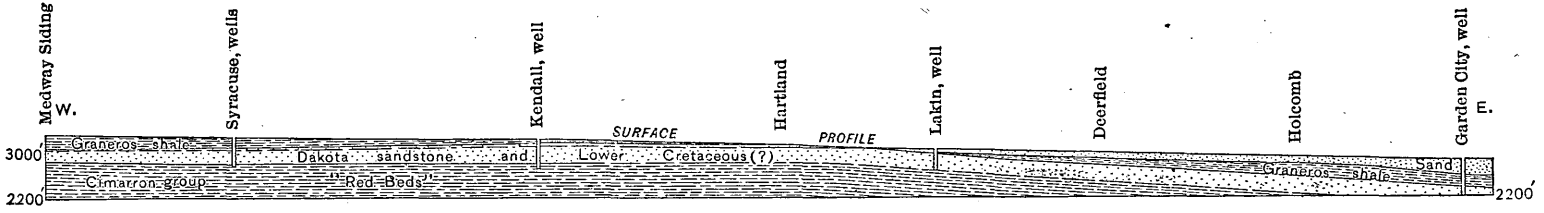


FIGURE 3.—Section showing underground relations of rocks along the Atchison, Topeka & Santa Fe Railway between Garden City and Medway, Kans. Vertical scale greatly exaggerated.

NORTHWESTERN KANSAS.

The northwestern part of Kansas is underlain by a thick body of later Cretaceous shale, chalk, and sandstone, covered by a mantle of Tertiary sand, gravel, and grit. The Pierre shale and Niobrara chalk and shales are revealed in the larger valleys, and although to the eye the beds appear to lie flat they dip in various directions. In Decatur and Sheridan counties they slope to the northwest on the west side of an anticline whose axis lies near longitude 101°. In the

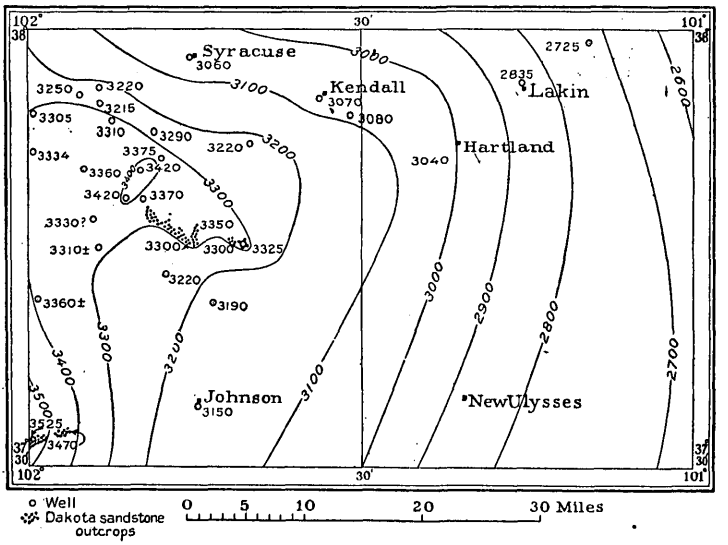


FIGURE 4.—Diagram showing structure of Dakota sandstone in Syracuse and Lakin quadrangles, Kans. Contour lines and figures show elevation of Dakota sandstone above sea level.

counties to the west and south the dips are mostly to the north, into the deep basin in the extreme northwest corner of the State. In Gove County the beds lie nearly horizontal. Doubtless there are many local variations in the direction and rate of dip, but they are difficult to detect in the shales, especially as in wide areas these rocks are covered by the Tertiary deposits. Deep borings have been made at many places in western Kansas. All those of which information has been received are given in the following table:

Deep borings in Kansas west of longitude 100°.

Locality.	Depth (feet).	Results.
Decatur County:		
Oberlin	800–1,000	No result.
Jennings	1,050	Much water.
Kanona	1,620	Do.
Finney County:		
Garden City, ½ mile northwest	1,000+	No result.
Garden City	902	Do.
Garden City, 8 miles south	1,250	Do.

Deep borings in Kansas west of longitude 100°—Continued.

Locality.	Depth (feet).	Results.
Ford County:		
Dodge City	800	No result.
Greeley County:		
Horace	1,370	Dakota sandstone at 1,050 feet.
Greenwood County:		
Eureka	1,255	Brine at 499 feet.
Neal, near	932	Oil.
Hamilton County:		
Syracuse	1,000	No results.
Haskel County:		
Santa Fe	1,300	Do.
Meade County:		
Meade	800	Red beds at 200 feet; salt.
Mitchell County:		
Asherville	638	Much salt water.
Morgan County:		
Redfield	700	Water.
Pawnee County:		
Larned	756	Salt water.

NEBRASKA.

The general geologic structure of Nebraska is shown in figure 5.

SOUTHEASTERN NEBRASKA.

The greater part of southeastern Nebraska is underlain by the Dakota sandstone, above which in places are the Graneros shale and Greenhorn limestone. Limestones and shales of Pennsylvanian age come to the surface in Cass, Otoe, Johnson, Gage, Pawnee, Richardson, Nemaha, and Lancaster counties. Nearly all of the upland is covered by glacial drift and loess, and the larger valleys are occupied by loess and alluvium. Owing to these surficial deposits, rock outcrops are far apart, and there is difficulty in determining the stratigraphy and structure. The Dakota sandstone and overlying shales dip west at a very low angle, and in places they may form domes, notably one a few miles west of Lincoln and another near Cortland.[1] The underlying Carboniferous rocks appear to lie nearly horizontal or to dip to the west and south, but on close examination the structure is found to be complex, with many local variations in direction and amount of dip. In a recent study of the rocks along Missouri, Platte, Weeping Water, and Big Nemaha rivers Condra and Bengtson[2] have found a general rise of the strata toward an anticline whose crest is near Oreapolis and Plattsmouth, and there is a deep basin in Nemaha County.

Numerous deep borings have been made in southeastern Nebraska without finding oil or gas. The principal ones are given in the list on page 10. The deepest boring is the 3,010-foot hole at Ne-

[1] See contour map, Darton, N. H., Underground waters of a portion of southeastern Nebraska: U. S. Geol. Survey Water-Supply Paper 12, pl. 20, 1898.

[2] Condra, G. E., and Bengtson, N. A., The Pennsylvanian formations of southeastern Nebraska: Nebraska Acad. Sci. Pubs., vol. 9, No. 2, 1915.

braska City, entirely in limestone, shale, and sandstone. The old 2,463-foot hole at Lincoln appears to have entered pre-Cambrian quartzite at 2,192 feet,[1] but the identity of the rock is not fully established. The many deep artesian wells at Omaha yield large supplies of excellent water from sandstone under the Carboniferous limestones and shales.

NORTHEASTERN NEBRASKA.[2]

Most of the surface of northeastern Nebraska is covered by glacial drift or loess, and outcrops of rocks are scarce. The rocks consist of the Dakota sandstone overlain by strata of Benton and Niobrara age and underlain by Carboniferous limestones, which were penetrated by a hole at Ponca and by many deep artesian wells in Omaha. In general the rocks dip due west at a very low angle into a basin whose axis lies in Rock, Brown, and northwestern Cherry counties. Near and northwest of Niobrara the dip is to the southwest, into this basin. Doubtless there are other variations in the direction of dip, and possibly minor anticlines and synclines interrupt the general monocline.

Deep borings have been made at many places, which are listed below. In Knox, Cedar, Boyd, and Dixon counties there are many

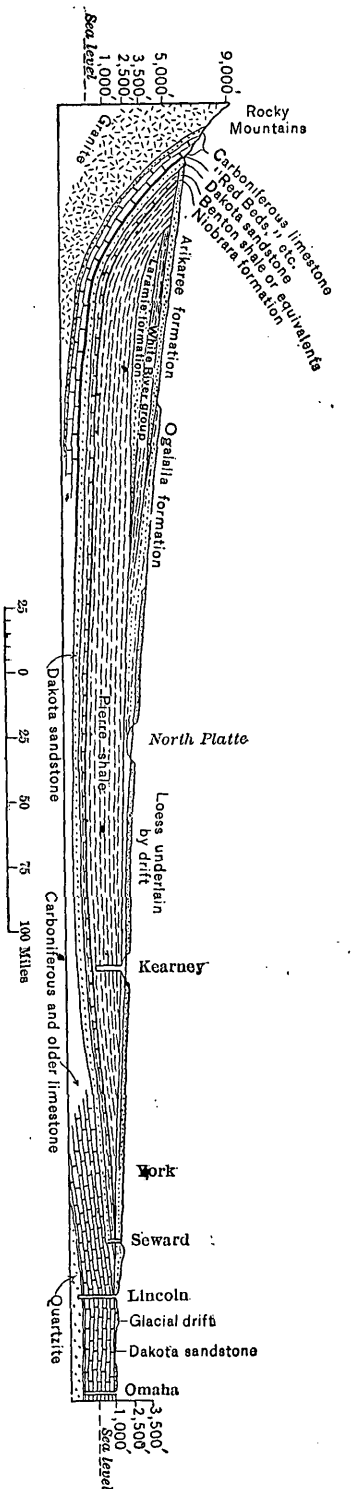


FIGURE 5.—General section across Nebraska from Omaha to the Rocky Mountains.

[1] Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, p. 283, 1905.

[2] The geology of the northeasternmost counties is described by G. E. Condra (Geology and water resources of the Missouri River valley in northeastern Nebraska: U. S. Geol. Survey Water-Supply Paper 215, 1908).

artesian wells drawing from the Dakota sandstone at depths of 400 to 600 feet.

Deep borings in Nebraska.

Locality.	Depth (feet).	Result.
Adams County:		
Hastings	1,145	Salt water at 940 feet.
Boone County:		
Albion	1,700	For coal; unsuccessful.
Boyd County:		
Lynch	923	Large flow of water from Dakota sandstone.
Buffalo County:		
Kearney	2,600?	In shale.
Dawes County:		
Marsland, near	927	Town well.
Chadron, near	1,800	No product.
Chadron, 12 miles northeast	1,000	"Failed to reach Dakota sandstone."
Douglas County:		
Omaha	1,101–1,383	Artesian wells.
Willow Springs	1,700	Do.
Omaha, 7 miles west	1,430	Do.
Furnas County:		
Cambridge	1,800	No product.
Arapahoe	912	Do.
Gage County:		
Beatrice, near	1,260	Artesian well.
Holt County:		
O'Neill	1,300	Unsuccessful.
Hooker County:		
Demerit farm	1,200	Artesian well.
Howard County:		
Dannebrog	1,011	Unsuccessful.
Lancaster County:		
Lincoln, Salt Beach	2,463	Flow of brine at 600 feet.
Lincoln, Square	1,050	Flow of brine at 560 and 1,050 feet.
Merrick County:		
Silver Creek	1,700	Water.
Nemaha County:		
Brownville	1,001	For coal; brine at 242 feet.
Otoe County:		
Nebraska City	3,010	
Pawnee County:		
Duboise, south of	562	Struck crystalline rock.
Richardson County:		
Falls City	1,300	Unsuccessful.
Rulo, 2 miles west	1,370	Do.
Sarpy County:		
Deerfield	1,450	Water.
Seward County:		
Seward	610	Unsuccessful.
Thayer County:		
Hubbell	725	Small amount of water.
Wheeler County:		
Ericsson	905	Unsuccessful.

SOUTHERN NEBRASKA.

The rocks exposed in central-southern Nebraska are the Dakota sandstone, 200 to 300 feet thick; shale and limestone of Benton age, about 270 feet thick to the east and probably 500 feet or more to the west; the Niobrara formation, 350 feet thick; the Pierre shale, which is at least 1,500 feet thick near the Colorado State line; and the cover of Tertiary grit and sand on the plateaus and alluvium in the valleys. The Dakota sandstone contains members of clay; the formations of Benton age comprise the Graneros shale at the top, the Greenhorn limestone, 25 to 50 feet thick, in the middle, and the Carlile shale at the bottom; the Niobrara has a basal member of chalky limestone, and the upper part is chalk and shale. Below the Dakota sandstone

to the east is a thick succession of limestones and shales of Carboniferous age; to the west there are probably "Red Beds" of considerable thickness, but their stratigraphic relations are not known.

The following quotation from Condra's report[1] gives the principal facts as to the structure of south-central Nebraska:

In southern Nebraska the rocks lie nearly horizontal, but, as shown in the section [fig. 6], with a general westerly inclination, interrupted near Cambridge by a low uplift or arch discovered by Mr. Darton several years ago. This arch develops in northwestern Kansas and extends northwestward across Nebraska. Its configuration is defined by the relations of the Niobrara formation, which is uplifted 200 feet or more near the crest of the arch, in the vicinity of Cambridge. From the crest the Pierre shale and 100 feet or more of the Niobrara have been eroded in the central and western portions of Furnas County. On the west side of the anticline the strata dip westward at an unknown but moderately rapid rate, so that in the extreme southwestern corner of Nebraska the top of the Niobrara formation is at a depth of about 2,000 feet, judging by the structure in adjoining portions of Colorado. East of the anticline there is a shallow syncline which holds Pierre shale from Arapahoe east to Naponee; thence eastward the strata rise gradually, and formations from Niobrara to Dakota outcrop in regular succession in the counties from Franklin to Jefferson. In general, the rate of inclination is regular and averages 3 feet in a mile. Locally, however, the rate is very much increased, especially in portions of Jefferson County. A local flexure is presented by the Greenhorn limestone in the southern portion of Jefferson County, and steep local dips of 10° or more occur to the southwest, in the exposure of Dakota sandstone south of Thompson, Nebr. The Dakota formation presents also a low anticline in the vicinity of Thompson and Gladstone, with the upper part of the arch removed by erosion. Faults, showing a few inches of displacement, occur in the Niobrara chalk in a number of places.

From the inclination of the rocks in the Medicine Creek valley northwest of Cambridge, it was believed that the axis of the anticline rises somewhat to the north and that a dome occurs in its crest near Stockville.

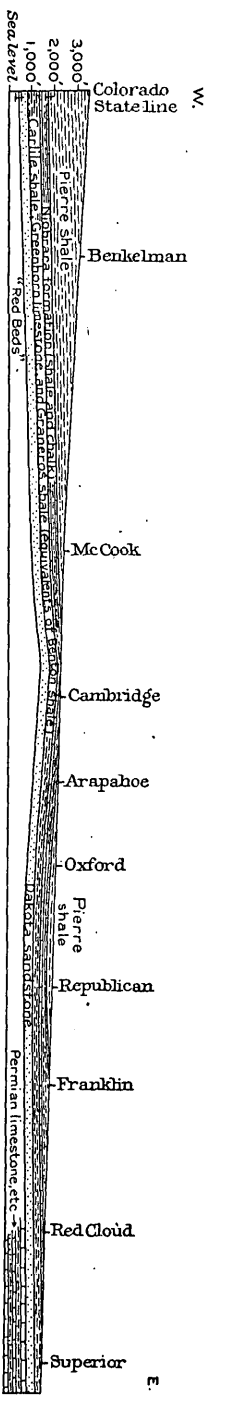


FIGURE 6.—Section along Republican Valley in southern Nebraska.

[1] Condra, G. E., Geology and water resources of the Republican River valley and adjacent areas, Nebraska: U. S. Geol. Survey Water-Supply Paper 216, p. 11, 1908.

Owing to the cover of Tertiary deposits on the plains adjoining the Republican Valley, this arch could not be traced north or south, but it appeared probable that it may extend across western Nebraska to the Chadron dome, as shown on the map (Pl. I). To the south there was some evidence of its extension in the valleys of Beaver, Sappa, and Prairie Dog creeks, its axis passing along the west side of Norton County and the east side of Sheridan County and dying out near Gove.

Few deep borings have been made in southern Nebraska. A 1,800-foot hole was recently put down near Cambridge, a boring 912 feet deep was made at Arapahoe, one 1,575 feet deep was made 1 mile east of Stockville, and there is a 405-foot hole at McCook. None of these borings are deep enough to test all the strata.

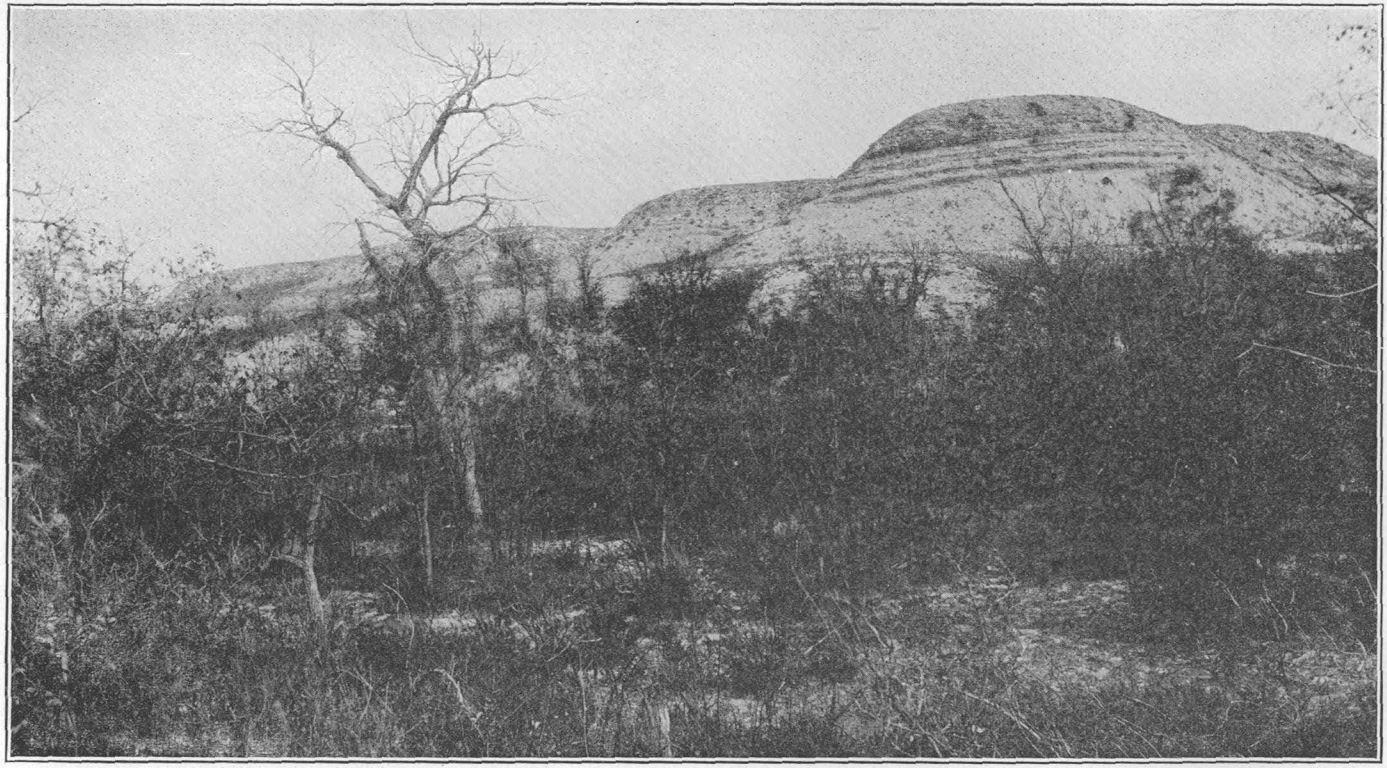
WESTERN NEBRASKA.

Most of western Nebraska is covered by so thick a sheet of Tertiary sands and clays that no knowledge of the underlying rocks could be obtained. To judge from evidence in adjoining areas, the region is underlain by Cretaceous rocks, probably in general dipping southwestward toward the Denver Basin. A small amount of late Cretaceous sandstone appearing in the western part of Scotts Bluff County gives strength to this view. It is probable that western Nebraska is underlain also by several hundred feet of Paleozoic limestones and sandstones, but no facts are available as to their structure. The Cambridge anticline may pass through Sheridan County to connect with the Chadron anticline, as shown on Plate I, but there are no exposures to throw light on this assumption. The relations of the anticline are, however, well exhibited in the northeast corner of Dawes County, northeast of Chadron, and in the adjacent portion of South Dakota. Several old holes sunk near Chadron were not sufficiently deep to test its possibilities as to oil or gas. One of these holes, a short distance north of Chadron, was reported to be 1,800 feet deep in 1904, but was discontinued in shale and sandstone of Benton age.

SOUTH DAKOTA.

CHADRON ANTICLINE AND SOUTHWESTERN SOUTH DAKOTA.

A well-defined arch of the strata in the region northeast of Chadron, Nebr., extends for some distance into South Dakota. As stated above, it is possible that this anticline extends southeastward across Nebraska, but owing to the continuous cover of Tertiary deposits the relations in that direction could not be determined. The struc-



OUTCROP OF CHALK OF NIOBRARA FORMATION IN SOUTHWESTERN PART OF SHANNON COUNTY, S. DAK.

ture is best shown on White River at the State line, where the chalk rock of the Niobrara formation shows an arch and the underlying Carlile shale is revealed in the river valley. A view of part of the chalk-rock exposure is shown in Plate II. The Niobrara exposure extends south of Slim Butte to Slim Butte Creek and some distance east of White River. At the Pine Ridge Agency, where the Pierre shale is exposed, the Niobrara is not far below the surface. The amount of uplift indicated by the presence of this formation is about 1,100 feet. Some features of its configuration are shown in Plate III. To the west there is a deep basin, on the farther side of which the strata rise on the flank of the Black Hills uplift, as shown in figure 7.

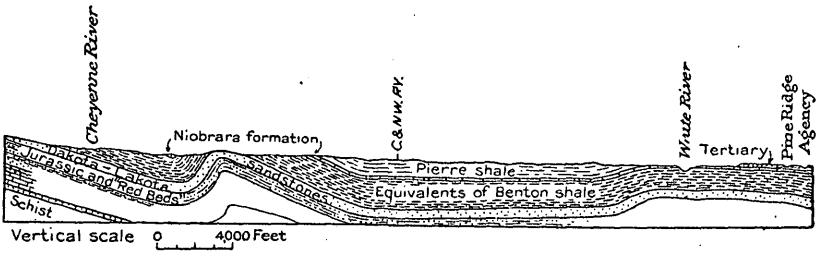


FIGURE 7.—Sketch section from Pine Ridge Agency, S. Dak., to Black Hills. Vertical scale exaggerated one-third.

Some holes, 1,000 and 1,800 feet deep, have been bored on or near this anticline in the vicinity of Chadron, but no records or other facts have been reported.

The structure of the portion of southwestern South Dakota west of the Chadron anticline is shown by contours in Plate I and by the cross section, figure 7. The salient features are the downward-pitching extensions of crenulations of the Black Hills dome. There are three principal anticlines strongly marked by moderately steep dips in many formations from the upper members of the Carboniferous to the Pierre shale. A detailed description of the geology of the area is given in the Edgemont[1] and Oelrichs[2] folios. The rocks that underlie the region are shown in the left-hand column in figure 8.

The artesian wells at Edgemont penetrated these rocks from the lower part of the Graneros shale to the Deadwood formation, as shown in figure 9. Slight indications of oil and gas were reported from one of the holes, but no facts were obtained as to depth or quantity. Evidently no useful supply was indicated. Two borings

[1] Darton, N. H., and Smith, W. S. T., U. S. Geol. Survey Geol. Atlas, Edgemont folio (No. 108), 1904.

[2] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Oelrichs folio (No. 85), 1902.

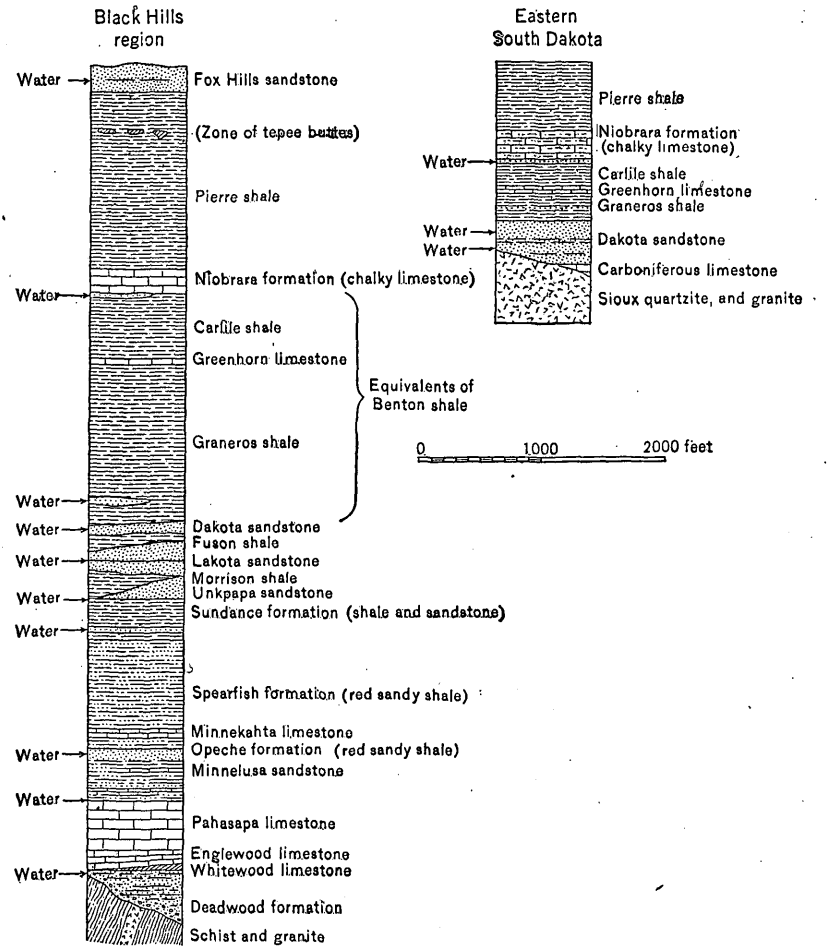


FIGURE 8.—Columnar sections of sedimentary rocks underlying South Dakota.

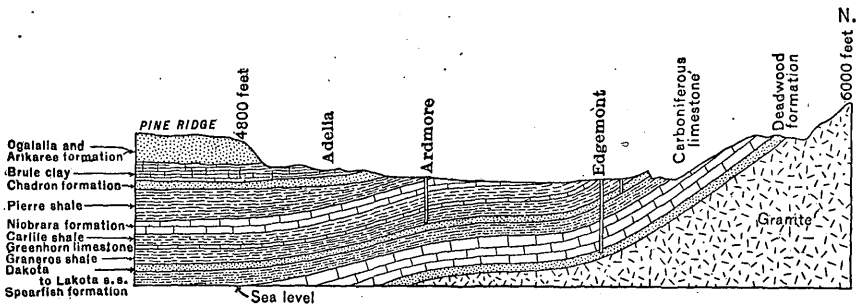


FIGURE 9.—Section from Black Hills through Fall River County, S. Dak., to Pine Ridge, Nebr. Shows relations of 2,980-foot wells at Edgemont.

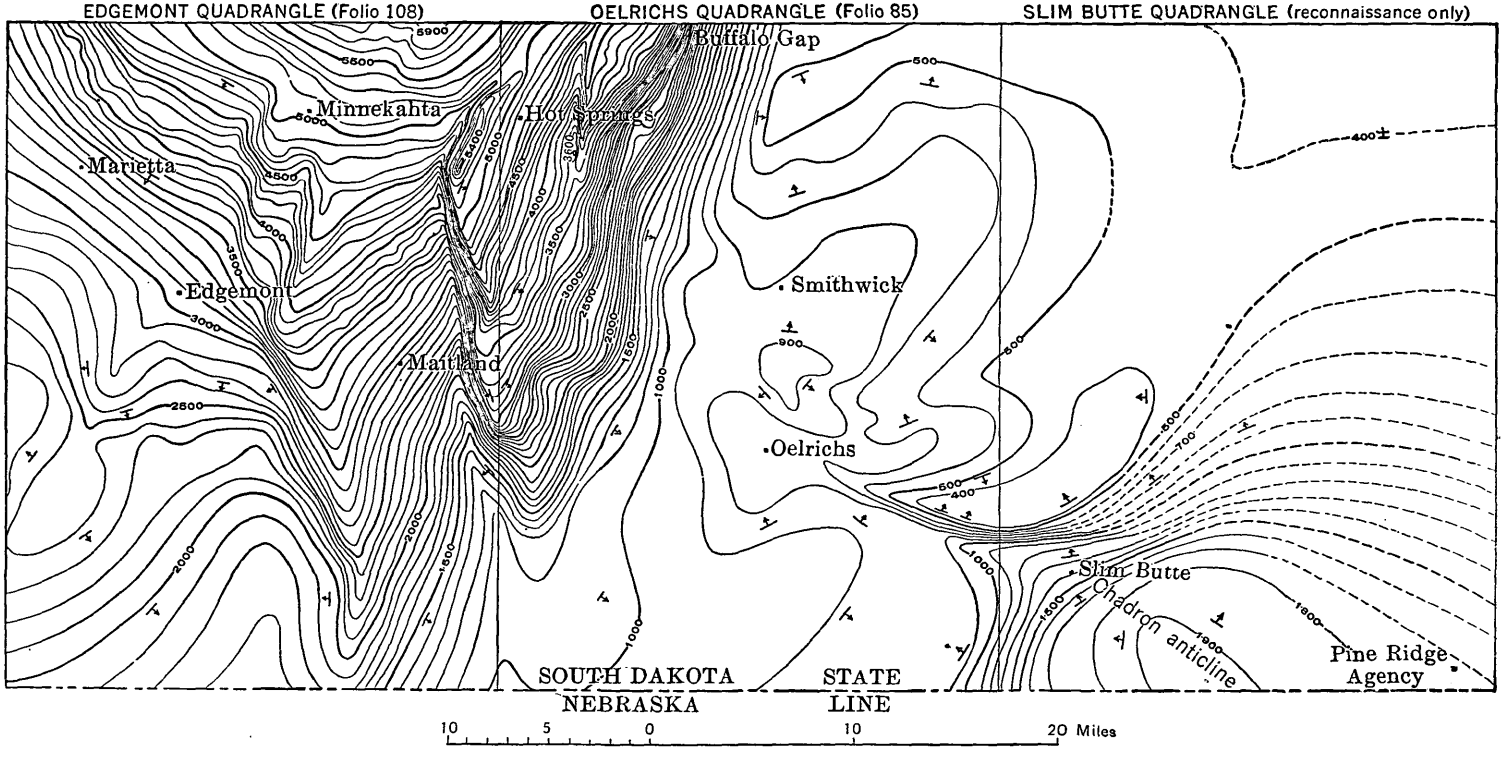


DIAGRAM SHOWING STRUCTURE OF PARTS OF FALL RIVER AND SHANNON COUNTIES, S. DAK.

about 800 feet deep were made at Buffalo Gap; the one in town stopped in shale; the other, near the foot of the hills, reached the Dakota sandstone.

CENTRAL SOUTH DAKOTA.

Central South Dakota is underlain by a thick body of Pierre shale, below which is the usual succession of beds of Niobrara and Benton age, Dakota and associated sandstones, and possibly the attenuated eastern margins of some of the lower sedimentary rocks exposed in the Black Hills. To the west there may be 3,000 to 4,000 feet of strata; to the east near Missouri River the depth to granite or quartzite is between 1,200 and 1,500 feet. In the eastern area the prospects for valuable quantities of oil or gas are not favorable. Figure 10 shows the general relations.

The strata lie very nearly level under a wide area in the great syncline between the Black Hills uplift and the Sioux quartzite ridge. Apparently, as shown by contour lines in Plate I, the general dip is to the north, toward the deep basin in Perkins County. Doubtless there are many subordinate undulations of the strata with domes in which gas or even oil might be found. Small volumes of gas occur mixed with artesian water at Pierre and under a district extending a few miles north of that place. Borings for artesian water have been made at intervals along the Chicago & Northwestern Railway and the Chicago, Milwaukee & St. Paul Railway extensions to Rapid City, but they have continued only to the Dakota sandstone, as has also a 2,600-foot boring made several years ago 20 miles northeast of the Rosebud Agency. Data regarding these borings are given in the table on page 16.

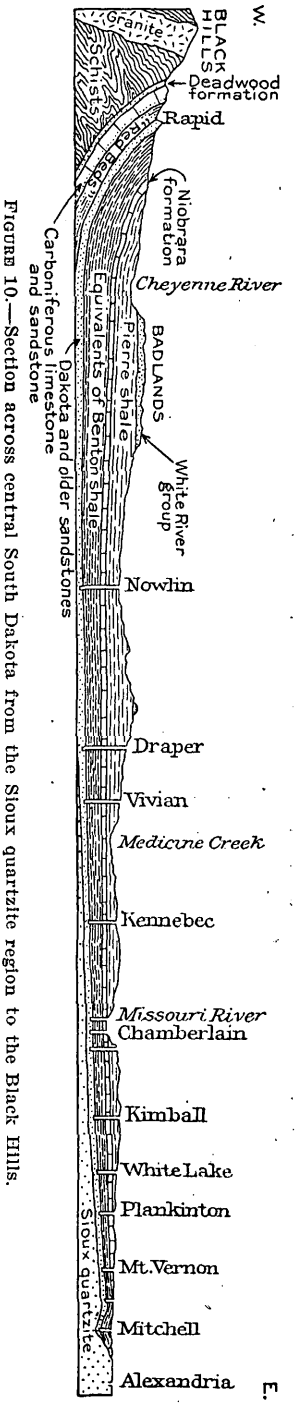


FIGURE 10.—Section across central South Dakota from the Sioux quartzite region to the Black Hills.

Deep borings in South Dakota west of Missouri River.

Locality.	Depth (feet).	Formations penetrated.	Results.
Butte County:			
Belle Fourche region	300–2,019	Pierre to Dakota	Many artesian wells.
Vale	2,215	do	Small flow of water.
Custer County:			
Buffalo Gap	700+	Graneros	No result.
Buffalo Gap, 1 mile west	800	Graneros and Dakota	Water.
Dewey County:			
Cheyenne Agency	1,337	do	Large flow of water.
Fall River County:			
Edgemont	2,980	Graneros to Deadwood	Artesian wells.
Ardmore	1,500	Niobrara to Graneros	No result.
Argentine	550	Graneros and Dakota	Artesian well.
Minnekahta	1,348	"Red Beds"	No water.
Gregory County	714–890	Niobrara to Dakota	Several artesian wells.
Lawrence County:			
Spearfish	312–415	Spearfish to Minnelusa	Do.
Do	1,610	Spearfish to Deadwood	Some water.
Lyman County:			
Capa	1,689	Pierre to Dakota	Artesian well.
Murdo, McKenzie	2,135	do	Some water.
Draper	2,005	do	Artesian well.
Vivian	1,610	do	
Kennebec	1,301	do	
Oacoma	730	Niobrara to Dakota	Do.
Meade County:			
Near Sturgis	570–1,560	Graneros and Dakota	Artesian wells.
Fort Meade	1,450	Graneros to Minnekahta	
Meyer County:			
Rosebud, 20 miles northeast	2,600	Pierre to Dakota	Water; no flow.
Pennington County:			
Wasta	2,287	Pierre to Graneros	Small supply of water.
Stanley County:			
Nowlin	1,842	Pierre to Dakota	Artesian well.
Wendte	1,395	do	Do.

EASTERN SOUTH DAKOTA.

The underground geology of eastern South Dakota has been determined by more than a thousand borings for artesian wells. Many of these have reached granite or quartzite bedrock, which lies from 50 to 1,600 feet below the surface, and none of them have found oil. Gas, however, has been obtained in small amount, mingled with the artesian water at Pierre and in a district of modern extent north and northeast of that place. The strata in this region are shown in figure 8. They are probably too thin to present prospects for any commercial supplies of oil or gas. The structure of the Dakota and associated sandstones, as determined by wells, is shown by the contours of the map (Pl. I). North of latitude 44° 30′ there is a general rise of the beds to the east; but the monocline bears a low dome, with its crest at Orient, and a shallow basin passes north and south through the center of Brown and Spink counties. Near latitude 44° the beds rise southward to a broad dome in which, however, the underlying floor of quartzite rises more steeply into an underground ridge. This ridge is not overlapped by the Dakota sandstone, but the beds of Benton and Niobrara age extend some distance up its slope. The quartzite is at or near the surface in a zone that passes through Alexandria and Sioux Falls.

Descriptions of the geology of eastern South Dakota are given in the Aberdeen-Redfield, Alexandria, DeSmet, Elk Point, Huron, Mitchell, Olivet, and Parker folios,[1] and a summary of the salient facts is given in my report on the geology and underground waters of South Dakota.[2]

NORTH-CENTRAL SOUTH DAKOTA.

The geology of the Cheyenne River and Standing Rock Indian reservations has been studied by Calvert, Beekly, Barnett, and Pishel.[3] These observers confirm the representation of structure shown on the map (Pl. I), stating that the beds of the Lance formation, Fox Hills sandstone, and Pierre shale are nearly horizontal, having a low dip to the northwest. They found several local faults which displace the beds a few feet, but in "some places the throw is as much as 100 feet."

NORTHWESTERN SOUTH DAKOTA.

The strata on the northeast slope of the Black Hills uplift comprise a continuous succession from the Deadwood formation to the Lance formation and have a general dip to the east and northeast, into a deep basin whose axis is at longitude 102° 30′ on the North Dakota-South Dakota boundary line. In the eastern part of Meade County the dips swing around to the north and northwest on the southeast slope of this basin. The structure of the part of the basin which contains lignite in Perkins and Harding counties has been worked out in detail by Winchester and his associates,[4] and in figure 11 is given a reproduction of their structure map with the contours renumbered to show the relation of the top of the Dakota sandstone. The original map shows the structure of the lower part of the Lance formation, which is about 3,700 feet above the Dakota sandstone according to my determinations of thickness in regions to the north and far to the southwest. It is stated that the coal field is in a very shallow basin, which deepens to the northeast, and whose center lies near or northeast of Lemmon. Along the western margin the beds show the steepest dip, notably in an area 20 miles southeast of Buffalo, where the direction is east and the rate about 65 feet to the mile. At the south end of Slim Buttes the dip is north and the rate about 25 feet to the mile. Near Meadow it is N. 10° W.

[1] Todd, J. E., and Hall, C. E., U. S. Geol. Survey Geol. Atlas, folios 165, 100, 114, 156, 113, 99, 96, and 97.

[2] Darton, N. H., U. S. Geol. Survey Water-Supply Paper 227, 156 pp., 15 pls., 1909.

[3] Calvert, W. R., Beekly, A. L., Barnett, V. H., and Pishel, M. A., Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, 49 pp., 8 pls., 1914.

[4] Winchester, D. E., Hares, C. J., Lloyd, E. R., and Parks, E. M., The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, 169 pp., 11 pls., 1916.

about 15 feet to the mile, and a few miles north of Bison N. 60° E. about 7 feet to the mile. Near Little Missouri River west of Cave Hills and Slim Buttes there are low anticlines, one of them a northern extension of the Glendive anticline of Montana. A second arch a short distance to the west brings up the Pierre shale in a small area south of the west Short Pine Hills, 15 miles south-southeast of Camp Crook. Very little faulting has occurred in this area, and the faults found had displacement of only 3 feet.

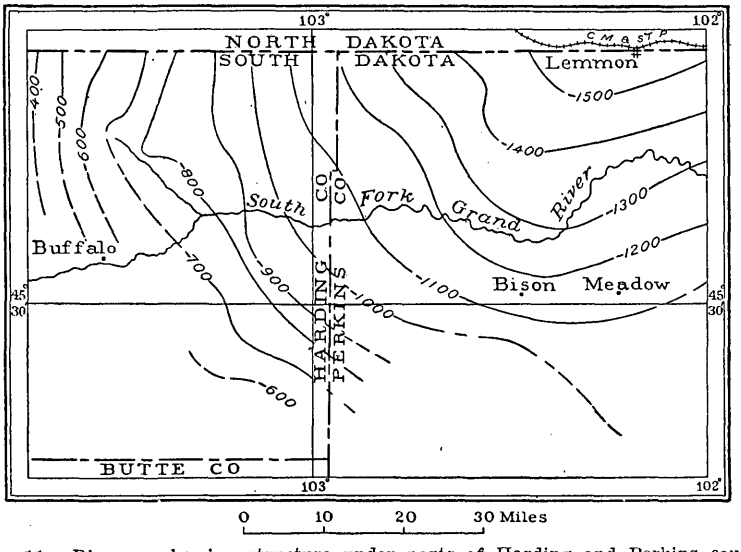


FIGURE 11.—Diagram showing structure under parts of Harding and Perkins counties, S. Dak. (After Winchester and others.) The contour lines are drawn at 100-foot intervals and show the approximate position of the top of the Dakota sandstone below sea level.

COLORADO.

NORTHEASTERN COLORADO.

The main structural feature in northeastern Colorado is the wide, deep basin whose lowest portion is a few miles northwest of Denver. Here the Dakota sandstone is somewhat below sea level, or more than 5,000 feet below the surface. Exposures of the Cretaceous rocks that occupy the basin are not very satisfactory, but apparently the beds have a low but continuous slope to the west or northwest. The steepest grade is probably in Kit Carson County and the northern part of Lincoln County, where the dip averages 40 to 50 feet to the mile, or about half a degree. Farther north the rate is much less, and possibly there is local doming. Near the Rocky Mountain front the strata are upturned steeply, but the monocline is traversed diagonally by anticlines and synclines of northwesterly trend, pitching down to the southeast. Some of these in the Boulder region have been de-

scribed by Fenneman[1] Oil occurs in sandy members of the Pierre shale in this area, as in the Florence Basin, and it is not unlikely that similar conditions may be found farther north and east in northeastern Colorado.

Many deep holes have been sunk at Denver and in its vicinity for artesian water, which is obtained from the Arapahoe and Denver formations. Several deep holes have been bored in the vicinity of Boulder for oil, some of them reaching the Dakota sandstone. A 1,700-foot hole at Castle Rock, a 1,440-foot hole at Sedalia, a 2,465-foot hole at Loveland, a 1,225-foot hole at Stout, a 1,155-foot hole at Akin, and a 2,400-foot hole at Otis all failed to reach the Dakota sandstone and therefore did not fully test the underground resources. Several artesian wells at Greeley and vicinity, from 1,165 to 2,260 feet deep, draw water from the Dakota or overlying sandstones.

East of Fort Collins there is a low anticline which extends for some distance north and south, parallel to the Rocky Mountain front. According to W. T. Lee, it is defined mainly by a group of sandstones in the Pierre shale, one member of which farther south is known as the Hygiene sandstone. The strata are arched up several hundred feet, presenting a condition favorable for oil or gas accumulation if these materials are present in the area. A boring was made 3,900 feet deep through 2,500 feet of alternating sandstone and shale of the Pierre formation and ended in shale believed to represent the shaly division (Apishapa shale) of the Niobrara. Doubtless this shale was near the base of that division, and the boring would have reached sandstone in the upper part of the Benton within the next 500 feet and the Dakota and underlying sandstones 1,500 feet or more farther down.

SOUTHEASTERN COLORADO.

The structure of southeastern Colorado is complex compared with that of other portions of the central Great Plains. The most striking features are a high dome centering on the Colorado-New Mexico State line in southeastern Las Animas County; a deep basin with its axis a few miles west of Trinidad; an arch passing west of Pueblo and rising into the front range of the Rocky Mountains to the north; a deep basin at Florence; a deep basin with bottom a few miles northwest of Denver; the steep eastward-dipping monocline along the foot of the mountains, interrupted by irregularities in northern Huerfano and western Pueblo counties; the dome and anticline in the northeast corner of Huerfano County; and a sharp local uplift due to igneous intrusion at Two Buttes.

[1] Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, 101 pp., map, pls., 1905.

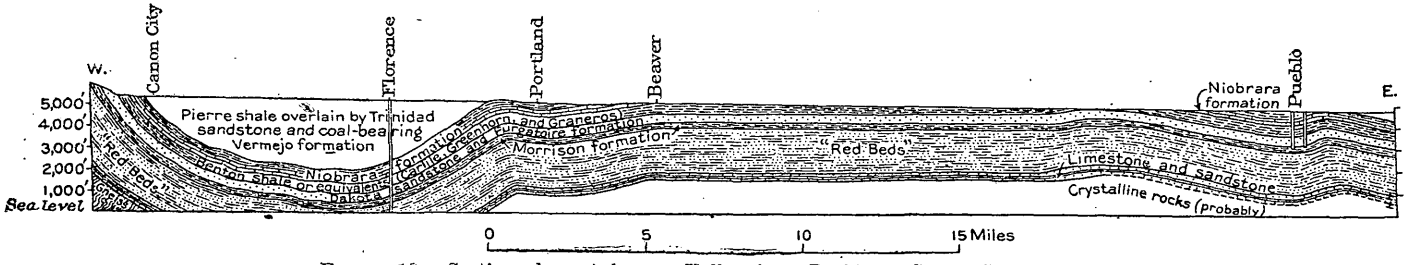


FIGURE 12.—Section along Arkansas Valley from Pueblo to Canon City, Colo.

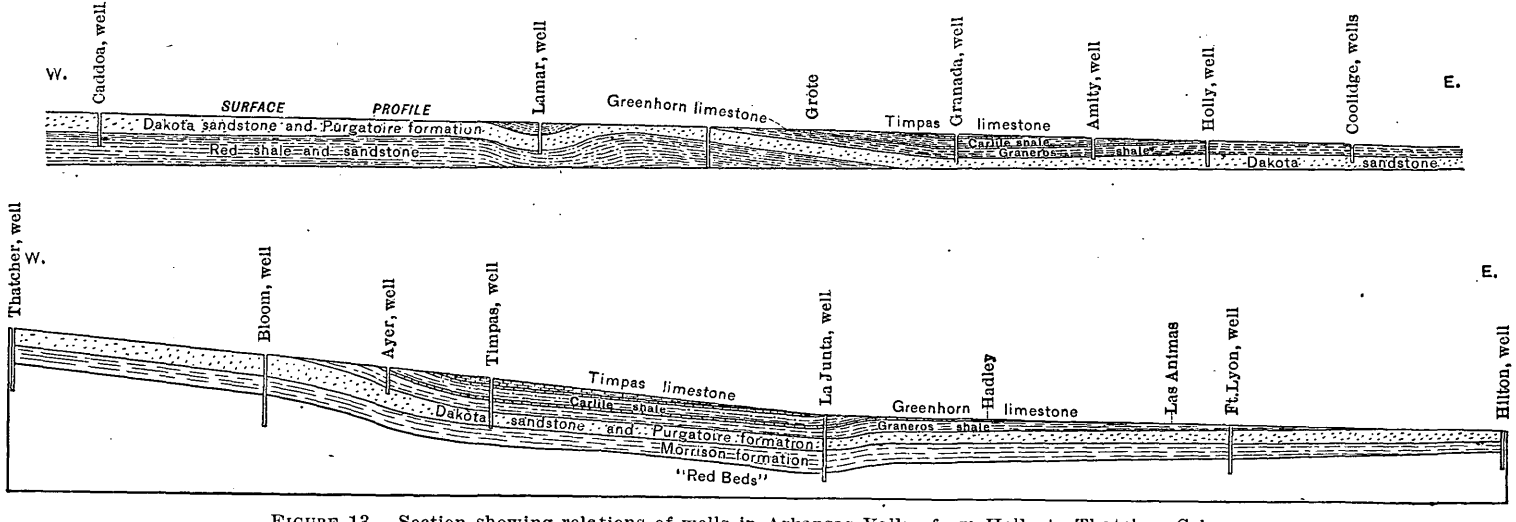


FIGURE 13.—Section showing relations of wells in Arkansas Valley from Holly to Thatcher, Colo.

The relations of these features are shown by the contours of Plate I, and further details are given in the Pikes Peak, Colorado Springs, Pueblo, Nepesta, Walsenburg, Apishapa, Spanish Peaks, and El Moro folios,[1] and in my report on the Arkansas Valley.[2]

Some general features are shown in the cross sections, figures 12, 13, and 14 and Plate IV, and details of structure in the Apishapa

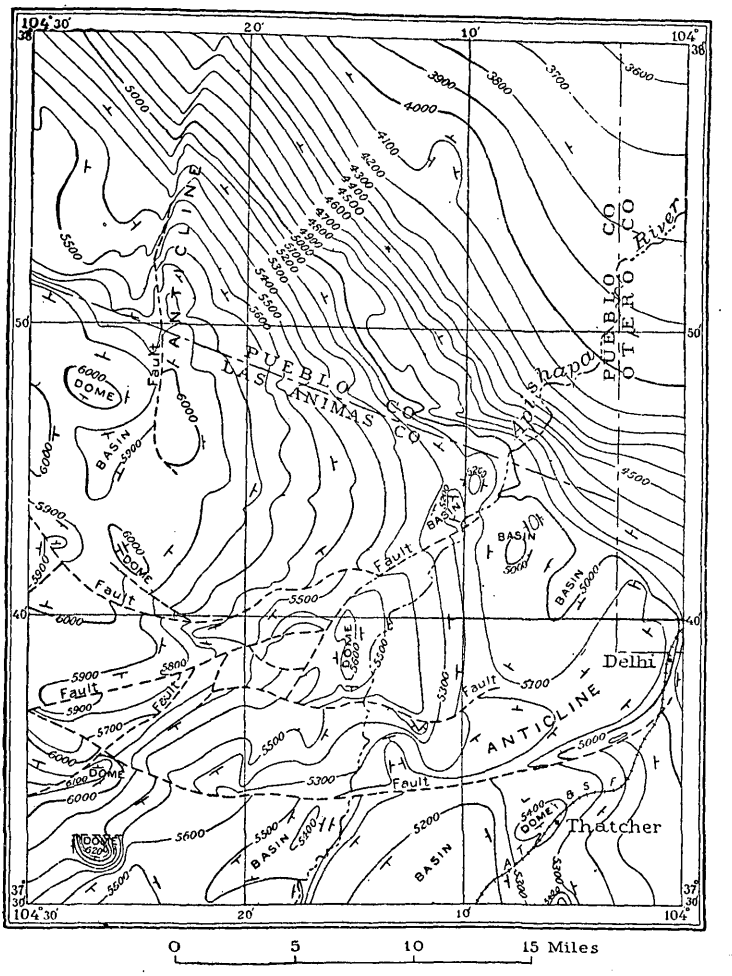


FIGURE 14.—Diagram showing structure in the Apishapa quadrangle, Las Animas, Huerfano, Pueblo, and Otero counties, Colo. The lines show the configuration of the Dakota sandstone, with its altitude above sea level. (After Gilbert and Stose.)

quadrangle are shown in figure 14, reduced from the structure-section sheet in the Apishapa folio. The succession and character of the formations are shown in the table on page 22.

[1] U. S. Geol. Survey Geol. Atlas, Folios 7, 203, 36, 135, 68, 186, 71, and 58.

[2] Darton, N. H., Geology and underground waters of the Arkansas Valley in eastern Colorado: U. S. Geol. Survey Prof. Paper 52, 90 pp., 28 pls., 1906.

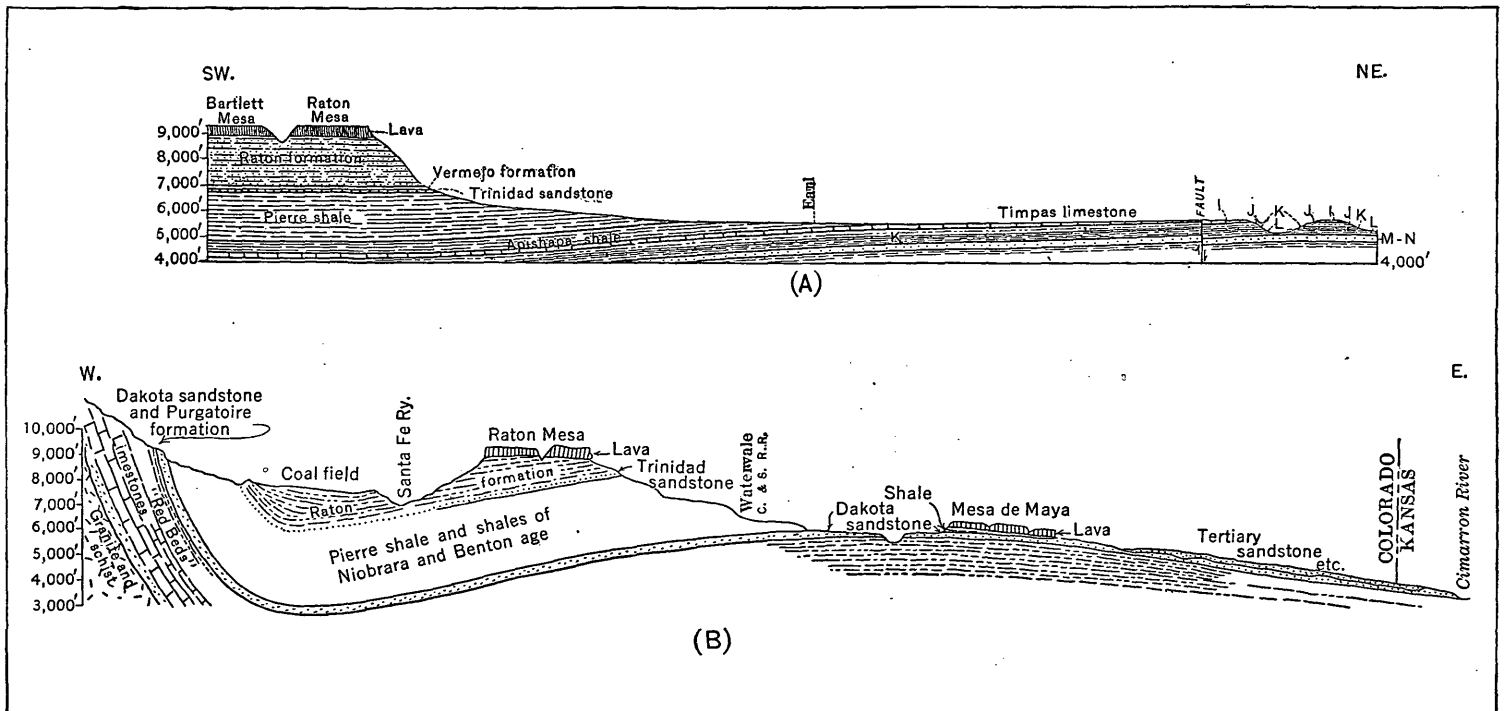
Geologic formations of southeastern Colorado, south of Denver Basin.

Age.	Formation.	Principal character.	Thickness (feet).
Quaternary		Sand, gravel, and loam Higher terraces, sand, gravel, and loam.	50 50
Pliocene (?)	Nussbaum formation	Sand, gravel, and conglomerate.	0–150
Eocene	Huerfano formation	Coarse sandstone and conglomerate on clays and marls.	0–2,900
	Cuchara formation	Massive sandstone; some clay	0–475
	Poison Canyon formation	Sandstone conglomerate; some clay.	0–1,900
	Raton formation	Sandstone and shale with coal beds.	1,800±
Upper Cretaceous	Vermejo formation	Gray sandstone and shale with coal.	0–450
	Trinidad sandstone	Massive sandstone	100
	Pierre shale	Dark-gray shale with concretions.	1,300–3,000
	Apishapa shale Timpas limestone (Equivalents of Niobrara limestone.)	Sandy shale, thin beds of limestone near top. Limestone and limy shale	550 200
	Carlile shale Greenhorn limestone Graneros shale (Equivalents of Benton shale.)	Dark shales with sandstone at top. Slabby limestone; shale partings. Dark shales	200 50 200
	Dakota sandstone	Gray sandstone, fire clay in middle.	200–300
Lower Cretaceous	Purgatoire formation	Soft sandstone and sandy clays.	20
Cretaceous (?)	Morrison formation	Gray to maroon joint clays with limestone and sandstone layers.	200
Triassic (?), Permian (?), and Pennsylvanian.	"Red Beds"	Bright-red sandy shales with thin limestone layers and gypsum; reddish sandstone at top. Fine-grained massive sandstones mostly red. Coarse red sandstone and conglomerates.	100 200 600–1,200
Mississippian	Millsap limestone	Gray and purplish limestone	20–200
Ordovician	Fremont limestone	Gray to pinkish dolomite, uneven grain.	100
	Harding sandstone	Fine, even-grained, gray to pink sandstone; some shale.	100
	Manitou limestone	Reddish dolomite	100–270
Upper Cambrian	Sawatch sandstone	Reddish sandstone	40–100
Pre-Cambrian	Granite, schist, etc.		

W. T. Lee has found that on the west slope of the great dome on the Colorado-New Mexico State line there is a small dike of cellular basalt which carries considerable petroleum. It crops out about 2 miles west of the Mexican village of Trinchera and doubtless derives the oil from some deep-seated sandstone. A hole said to be about 1,000 feet deep was sunk near this dike to the Dakota sandstone, but water came into the hole and boring was abandoned.

An old bore hole southwest of Barela, of unknown depth, yields considerable gas, which is piped to a near-by ranch for use.

Although numerous deep borings have been made in southeastern Colorado, most of them have penetrated no farther than the Dakota sandstone and have not tested the underlying beds. A few of the deeper holes, however, have been extended into the underlying red



SECTIONS ACROSS SOUTHEASTERN COLORADO.

I, Timpas limestone; J, Carlile shale; K, Greenhorn limestone; L, Graneros shale; M, Dakota sandstone; N, Purgatoire formation.

beds and sandstones. These wells are given in the following list. Some of the holes are shown in figures 12 and 13.

Deep borings in southeastern Colorado.

[This list does not include holes put down later than 1906.]

Locality.	Depth (feet).	Formations penetrated.	Results.
Las Animas County:			
Delhi	322	Graneros and Dakota	Water; no flow.
Tyrone	580	Timpas to Dakota	Do.
Trinidad	2,585–3,000	Pierre to Dakota	Do.
Barela	1,340	do	Do.
Hoehne	936	Pierre to Carlile	No water.
Thatcher	920	Dakota to "Red Beds"	Not much water.
Pueblo County:			
Pueblo, south	1,166	Timpas to Dakota	Mineral water.
Pueblo Iron Co.	1,260	do	Do.
Pueblo, Farris House	1,400	do	Do.
Pueblo, Grand Hotel	1,219	do	Do.
Pueblo, north	1,820	Timpas to "Red Beds"	Do.
Pueblo, 7 miles northeast	1,900	Pierre to Dakota	Little water.
Pueblo, 10 miles northeast	2,655	do	Do.
Boone	2,200	do	No product.
Fremont County:			
Florence	1,000–3,021	In Pierre	Many oil wells.
Portland, 10 miles south	1,135	Apishapa to Dakota	Large flow of water.
Chandler	1,075	In Dakota	Mineral water.
St. Mary	1,670	do	"Alkaline water."
El Paso County:			
Colorado City	2,020	Pierre	No product.
Franceville Junction	1,250	do	Do.
Otero County:			
Fowler, 2 miles east	1,372	Pierre to Dakota	Small flow of water.
Manzanola	1,113	Apishapa to Dakota	Large flow of water.
Do	2,110	Apishapa into "Red Beds"	Bad water.
Rocky Ford	767–1,032	Apishapa to Dakota	Large flows of water.
Holbrook	661	Graneros and Dakota	Flow.
Ordway	1,508	Pierre to Dakota	Water; no flow.
Sugar City	1,308	do	Do.
La Junta	405–555	Timpas to Dakota	Flow of water.
Do	1,150	Timpas to "Red Beds"	Nothing.
La Junta, 2½ miles south	1,730	do	Do.
Timpas	795	do	Bad water.
Bloom (Iron Springs)	1,162	Graneros to "Red Beds"	Small supply of bad water.
Bent County:			
Las Animas	360	Graneros and Dakota	Good flow of water.
Fort Lyons	815	Dakota to "Red Beds"	Small flow at 430 feet.
Caddoa	582	Dakota	Water; no flow.
Prowers County:			
Granada	504	Timpas to Dakota	Do.
Lamar	226–522	Dakota to "Red Beds"	Do.
Kiowa County:			
Sheridan Lake	1,280	Timpas to Dakota	Do.
Cheyenne County:			
Cheyenne Wells	1,700	Tertiary to Graneros	Small showing of gas.
Kit Carson	1,300	do	No water.
Huerfano County:			
Walsenberg	1,300	Pierre	No product.
Salt Creek	2,030	Pierre to "Red Beds"	Bad water.
Cuchara	800	Graneros and Dakota	Sulphur water.
Rouse Junction	2,058	Pierre to "Red Beds"	Little water.

WYOMING.

On the western slope of the Black Hills uplift there are several anticlines and domes that may contain oil or gas. They have been described in reports[1] and folios,[2] and some of their features are

[1] Darton, N. H., Preliminary description of the geology and water resources of the southern part of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 489–599, pls., maps, 1901; Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Prof. Paper 65, 105 pp., 24 pls., 1909. Barnett, V. H., The Moorcroft oil field, Crook County, Wyo.: U. S. Geol. Survey Bull. 581, pp. 105–112, 1915.

[2] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Newcastle folio (No. 107), 1904; Sundance folio (No. 127), 1905.

shown by the contour lines on Plate I. The occurrence of oil at Newcastle and northwest of Moorcroft, although so far not proved to be in commercial amounts, gives some encouragement for believing that reservoirs may yet be found at some localities in this general region.

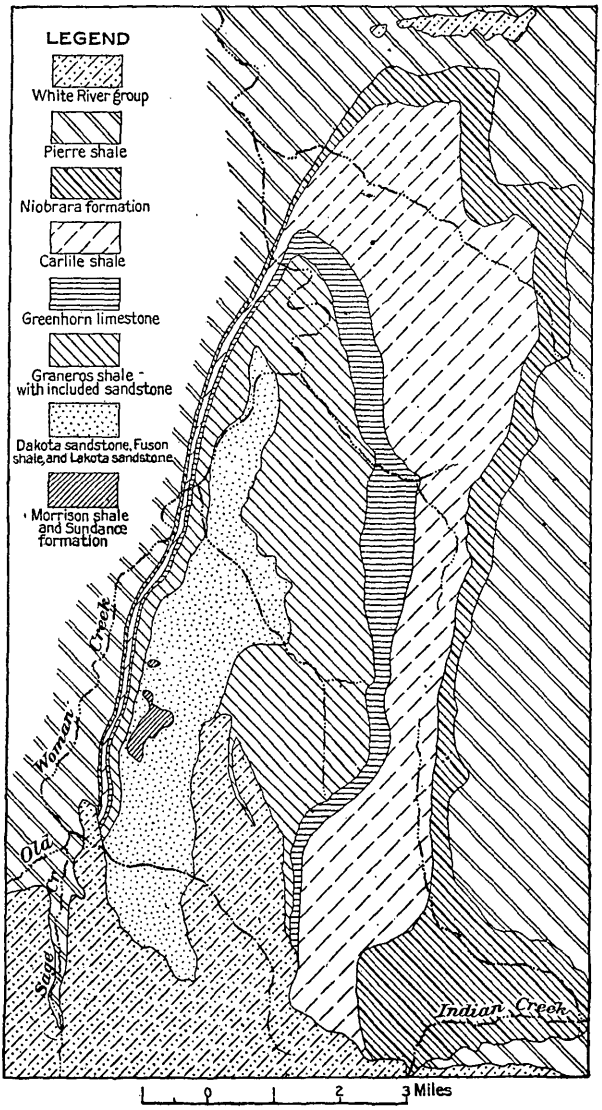


FIGURE 15.—Map of the anticline on Old Woman Creek, Converse County, Wyo.

An anticline of considerable prominence on Old Woman Creek, in Converse County, was described in 1901.[1] It is a prolongation of an uplift or series of uplifts extending from Rawhide Butte to Lusk but

[1] Darton, N. H., Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 4, pp. 552–554, 1901.

largely covered by Tertiary deposits. The anticline brings to the surface the Dakota to Lakota sandstones and associated formations, and a canyon near its crest reveals fossil-bearing shales in the upper part of the Sundance formation. The principal features are shown in the map (fig. 15) and cross section (fig. 16).

The central ridge of Dakota and Lakota sandstones is about 7 miles long. The dips on the west side are steep and nearly vertical in places, but the dip on the east slope is at a low angle, spreading the formations out in wide zones. The axial pitch to the south is slight, but the relations in that direction are concealed by sand and clay of the White River group. The pitch to the north is gradual, and the flexure is traceable in greatly reduced form to and beyond Cheyenne River at the mouth of Alkali Creek.

The formations that may possibly contain oil or gas in this uplift are the Minnelusa, Pahasapa, and Deadwood, which lie between 1,000 and 2,500 feet below the surface in the center of the anticline. A

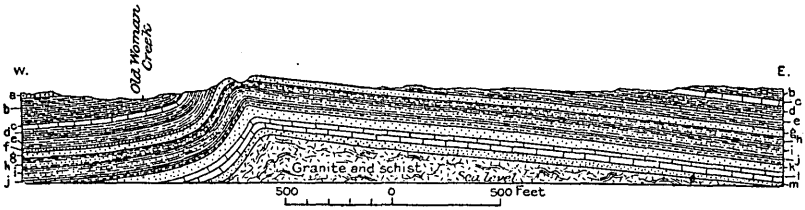


FIGURE 16.—Section across the anticline on Old Woman Creek, Converse County, Wyo. a, Fox Hills sandstone; b, Pierre shale; c, Niobrara formation; d, Carlile shale; e, Greenhorn limestone; f, Graneros shale with included sandstone member; g, Dakota sandstone, Fuson shale, and Lakota sandstone; h, Morrison shale and Sundance formation; i, Spearfish formation; j, Minnekahta limestone on Opeche formation; k, Minnelusa sandstone; l, Pahasapa limestone; m, Deadwood formation.

1,730-foot boring in this uplift has found considerable oil, doubtless in the Minnelusa sandstone, which is entered at 920 feet. It found "Red Beds" at 355 to 770 feet, underlain by 70 feet of Minnekahta limestone and 80 feet of red Opeche sandstone. These formations were penetrated by the two deep artesian wells at Edgemont, 25 miles northeast of Old Woman Creek, and at that place showed no indications of much oil.

In the vicinity of Newcastle there are two low-pitching anticlines on the west slope of the Black Hills uplift, details of which are given in the Newcastle folio and the report on the southern Black Hills above cited. In the Red Valley north of Cambria and southwest of Sundance there are low domes, the relations of which are shown in the Sundance folio. Two low elongated domes 18 miles north of Aladdin are shown in the Aladdin folio.

In the region northwest of Moorcroft there are two domes on a long, low anticline on the west slope of the Black Hills uplift. The summit of one dome is in sec. 30, T. 51 N., R. 66 W., and that of the other in the south side of sec. 11, T. 52 N., R. 67 W. Both of these

domes present outcrops of Morrison shale in their centers. Considerable drilling has been done in this area, and oil has been found in some wells, although the quantity appears to be small and not to offer much encouragement for profitable production. Up to 1913, however, some parts of the area had not been tested.

DEEP-SEATED STRUCTURE.

As most of the structure described in this paper is that of the Dakota and associated sandstones it is advisable to suggest that locally the same structure may not exist in the underlying formations. This difference is possible because there is an unconformity between

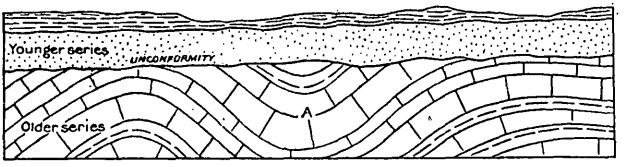


FIGURE 17.—Ideal section to show relations of flexures in an older formation under a monocline of younger rocks.

the Dakota and the beds below it, representing a long-time interval when the Permian and older Carboniferous strata were uplifted and their surface eroded prior to Purgatoire and Dakota deposition. This uplift was not attended by local flexing in the Black Hills, Rocky Mountain front range, southeastern Nebraska, and central Kansas, where the younger rocks lie on the older ones without noticeable discordance of attitude. If this relation prevails under the whole of the Great Plains area, which is not unlikely, the structure of the buried Permian and older Carboniferous rocks is indicated in a gen-

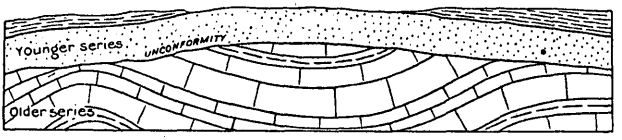


FIGURE 18.—Syncline in older strata persisting, although considerably flattened by a flexure that developed an anticline or dome in the overlying younger rocks.

eral way by the structure lines of the Dakota sandstone. (See Pl. I.) Some possibilities of a divergent structure which might exist locally are shown in figure 17. If a district of this sort were deformed so as to develop an anticline or dome in the younger series the relations shown in figure 18 might result. Future borings in the Great Plains should be carefully watched for evidence as to the structure of the buried Carboniferous rocks. This can be done by close sampling in boring and critical consideration of the stratigraphy revealed, as compared with the succession in the areas where the rocks crop out.