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Agate Anticline, Sioux County, Nebraska

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THE AGATE ANTICLINE, SIOUX COUNTY, NEBRASKA.

By E. F. SCHRAMM.
H. J. COOK.

INTRODUCTION.

The field study which furnished the basis for this report was made by the authors, at irregular intervals over a period of several years. The first detailed topographic map of the area described, was made in 1912 and the structural map completed in 1916.

In mapping both the topography and structure, major locations were established by means of triangulation, minor intervals read by stadia and elevations determined by means of vertical angles. The instruments used consisted of a heavy, Johnson head tripod with a 15 inch plane table and a standard size telescopic alidade. A base line was established between two section corners located in the Niobrara River valley. An elevation, approximating the true elevation was assumed, as a starting point. This bench mark was established at the west end of the base line, at the southeast corner of sec. 1, T. 28 N., R. 55 W. The assumed elevation was based upon contour elevations given on the United States Geological Survey Whistle Creek topographic sheet.

The structural map submitted with this report was checked in 1920 by Christian Vrang, geologist for the Associated Oil Company. Acting upon the favorable report of Mr. Vrang the Associated Oil Company entered into a contract with the parties owning the leases upon this structure to drill a deep test well upon the Agate anticline. This well is being drilled at the present time, the contract calling for a depth of 4,500 feet unless oil or gas are encountered in paying quantities at a lesser depth.

LOCATION.

The Agate anticline is located in Sioux County, Nebraska, in Tps. 28 and 29 N., Rs. 54, 55 and 56 W., of the 6th Principal Meridian. The west end of the structure is within 12 miles of the Nebraska-Wyoming state line.

In reference to proven structures it is located about 15 miles

south of Edgemont, South Dakota, and the Mule Creek Wyoming fields. The Mule Creek Oil field is located approximately on the Wyoming-South Dakota line just 4 miles from the east line of Wyoming and 25 miles north of the northwest corner of Sioux County, Nebraska.

The Lance Creek or Lusk oil field of Wyoming is located approximately 65 miles to the northwest of the Agate anticline, and 21 miles west of the northwest corner of Sioux County, Nebraska. The same major formations underlie the Agate structure as occur in the fields above mentioned, with the exception that the Agate anticline is covered by a greater thickness of Tertiary sediments. The Agate structure can be reached either from Andrews or Harrison, Nebraska, stations on the Chicago and Northwestern Railway. Andrews is located about 18 miles to the north and Harrison approximately 24 miles to the northwest of Agate postoffice. The east end of the anticline is about 20 miles west of Marsland on the Chicago, Burlington and Quincy Railroad. The Burlington and Union Pacific Railroads can also be reached to the south at Mitchell and Haig, Nebraska, in the valley of the North Platte River, 35 to 40 miles distant. There are excellent roads from all of the above mentioned towns to Agate. The main north and south highway through Sioux County from Mitchell to Harrison, Nebraska, passes through Agate.

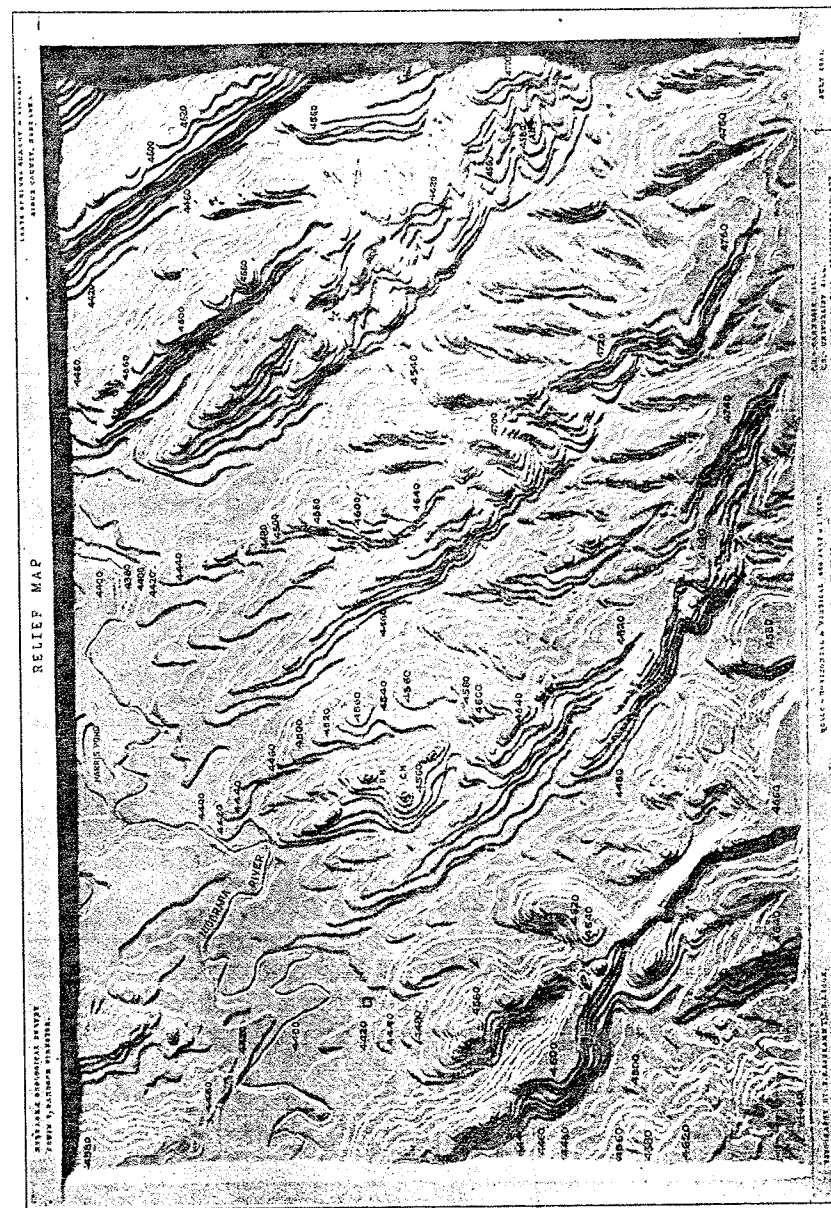
SURFACE FEATURES.

DRAINAGE AND TOPOGRAPHY.

The area described in this report is drained on the north by the Niobrara River and its tributaries, and on the south by small intermittent streams tributary to Snake and Whistle Creeks. The Niobrara River flows across the northern part of T. 28 N., Rs. 54, 55 and 56 W. The intermittent streams draining to the Niobrara River from the south all have a north westerly course with their sources located on or near the axis of the structure. The minor drainage lines outline rather definitely the structure of the Agate anticline.

The relief, especially on the north side of the structure is decidedly rugged, a common characteristic of the topography in Tertiary formations in semi-arid regions.

Deep narrow ravines have been cut into the surface forma-



RELIEF MAP OF A PORTION OF THE AGATE ANTICLINE.

□, Camp Buildings; U. H., University Hill; C. H., Carnegie Hill; A. H., Amherst Hill; Section lines. The northwest corner of map is the center of sec. 4, T. 28 N., R. 55 W. Topography by E. F. Schramm and H. J. Cook. Cut furnished by Dept. of Geology, University of Nebraska.

tions, which consist of the Monroe Creek, Upper and Lower Harrison beds, subdivisions of the Arikaree formation of Miocene age. The Monroe Creek member is well exposed in only a few places on the structure, the pronounced exposures being located near the crest in sections which have been deeply eroded by the larger intermittent streams. The Upper and Lower Harrison beds are composed in part of a gray limy sandstone consisting of approximately 65 per cent. sand and 35 per cent. calcium carbonate. It is comparatively soft and weathers readily, which accounts for the highly rugged topography. Numerous deep drainage lines have been cut on the north side of the Agate structure which gives a local relief of from 50 to 375 feet. The Niobrara River valley in T. 28 N., R. 55 W., has an elevation of 4,400 feet above sea level and the tops of the hills on the divides in the same township are represented by an elevation of 4,780 feet.

The Niobrara River is the only perennial stream within the area described. It has a gradient of about 15 feet to the mile and carries a strong flow of water throughout the year. The flow approximates 30 cubic feet per second. Wells drilled in the Niobrara valley produce an inexhaustible quantity of pure water. Water for use in drilling can be piped from shallow wells in the valley or from the Niobrara River. Excellent water bearing sands occur in at least two horizons in the Tertiary sediments covering the area herein described.

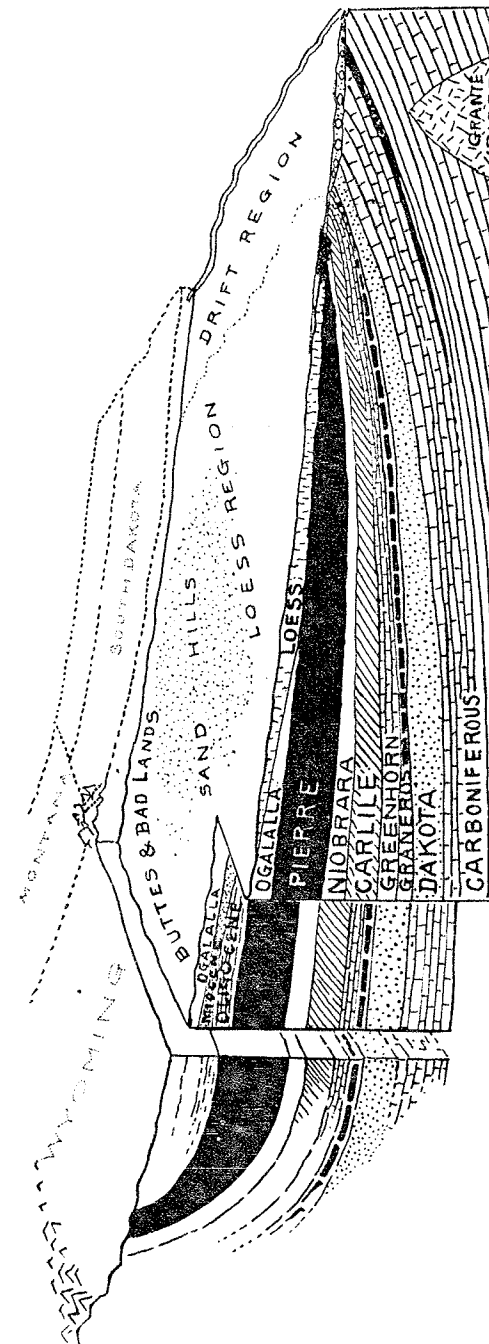
STRATIGRAPHY.

GENERAL SECTION.

The highest beds in the stratified series mapped and described in this report are represented by the Upper Harrison member of the Arikaree formation. The lowest exposed rocks consist of the pale salmon colored shales of the Monroe Creek beds, located in the lower part of the Arikaree formation of Miocene age.

The Lakota sandstone which is in the upper part of the Lower Cretaceous is probably not within drilling depth of the surface.

The formations intervening from the Lakota to the Monroe Creek beds consist of the Fuson shales, Dakota sandstone, Graneros shale, Greenhorn limestone, Carlile shale, Niobrara shale and limestone, Pierre shale, Chadron shale and sandstone, and the Brulé clay. Of the formations named, the Lakota, Dakota,



Vertical scale greatly exaggerated!

Fig. 1.—General section across Nebraska, showing the surface and underlying formations. The sub-surface granite ridge indicated in the extreme southeastern corner of the state extends entirely across eastern Kansas. (Sketch by E. H. Barbour.)

Graneros, Carlile and Pierre contain sands in other localities in the west which are known to be oil and gas bearing.

In the generalized section given in the following table the thickness of the formations in the upper part of the section was determined by measurements of exposed members and from the log to date, of the Associated Oil Company's well. The lower part of the section is compiled from United States Geological Survey published sections of the Mule Creek and Lance Creek oil fields and from logs of deep wells drilled in southeastern Wyoming and southwestern Nebraska.

Rock formations in the Agate, Nebraska, anticline.

System.	Series.	Group.	Formation and member.	Character.	Thickness (feet).
Quaternary.	Recent.		Alluvium and Gravel.	Sandy loam, rich alluvium in valleys.	Variable.
Tertiary.	Miocene.		Upper Harrison.	Calcareous sandstone and clay.	200
			Lower Harrison.	Coarse and fine grained sandstone.	200
			Monroe Creek or Rosebud. (Gering of Darton).	Salmon to buff colored shales, clay and sandstone.	200
	Oligocene.	White River formation.	Brule.	Pink to flesh colored hard, massive, somewhat sandy clay, with local lenses of sandstone near base, and volcanic ash near top.	670
			Chadron.	Greenish gray sandy shale with sandstone, and conglomerate near base.	100
Cretaceous.	Upper Cretaceous.		Pierre.	(The following characteristics of the Pierre on the Agate structure are taken from the log of the Associated Oil Company's well.) Yellowish stained shale with thin bands of bluish shale, with a small amount of sand grains in the lower part.	45

Rock formations in the Agate, Nebraska, anticline.—Continued.

System.	Series.	Group.	Formation and member.	Character.	Thickness (feet).
Cretaceous.	Upper Cretaceous.	Montana.	Pierre shale.	Pierre shale, interstratified occasionally with very thin shaly sandstones, called "shells" by the drillers. Fine grained sandy layers at 1460 feet with a showing of oil. Typical bluish gray	1,145
				(From description of the lower part of the Pierre in the Lance Creek Field. U. S. G. S. bulletin 716-E.) "Shannon" (?) sandstone member, coarse-grained greenish-gray sandstone with many yellowish-brown iron-stained concretions." The Shannon member is 130 feet thick in the Salt Creek Field.	16-50
				"Predominantly dark-gray shale, but including lenticular masses and some very thin beds of fossiliferous calcareous concretions." The Pierre shale in the Lance Creek field has a maximum thickness of 3300 feet. In Banner County, Nebraska, the combined thickness of the Laramie and Pierre is 2831 feet. In the Edgemont quadrangle the thickness is approximately 1200 feet. At Wray, Colorado, 9 miles from the Nebraska state line, it varies from 1490 to 1590 feet.	1,950
			Niobrara formation.	Soft, gray to cream colored shaly limestone or impure chalk, interstratified with some sandy shale layers.	185-200
				Carlile shale.	Dark gray shale with thin beds of soft sandstone (oil bearing Wall Creek sandstone member) near the base.
Cretaceous.			Greenhorn limestone.	Gray impure thin bedded limestone, fossiliferous.	50

Rock formations in the Agate, Nebraska, anticline.—Continued.

System.	Series.	Group.	Formation and member.	Character.	Thickness (feet).	
Cretaceous.	Upper Cretaceous	Colorado.	Graneros shale.	Dark gray to black shale, including many large calcareous and arenaceous concretionary layers in upper part. Concretionary layers very pronounced near Chadron, Nebr.	575	
				Mowry shale member.	"Hard light-gray sandy shales containing numerous fish scales. Contains bentonite beds near the top and to some extent near the base."	100
					"Dark sandy shale grading upward into typical Mowry shale."	25
				Newcastle sandstone member.	"Reddish to light-yellow sandstone associated with black carbonaceous shale." (Oil bearing.)	3-50
					"Dark gray to black shale."	175
			Dakota sandstone.	Buff to brown sandstone thin bedded and hard in some localities, soft and friable in eastern Nebraska.	60-150	
	Fuson formation.	"Shale and thin-bedded sandstone."	20			
Lower Cretaceous.			Lakota sandstone.	"Sandstone in part conglomeratic with some coal beds, near the base." Oil Bearing in Mule Creek field.	200	

UNEXPOSED ROCKS.

CRETACEOUS SYSTEM.

LOWER CRETACEOUS SERIES.

The Lower Cretaceous rocks of the Black Hills region are represented by the Lakota sandstone and the Fuson formation. These formations outcrop on the south side of the Black Hills

uplift in the vicinity of Edgemont, South Dakota, about 18 miles north of the Nebraska-South Dakota state line.

The Lakota sandstone is composed of gray to brown massive sandstone, usually coarse grained and cross-bedded, interstratified with thin beds of shale. The lower part of the formation contains lenticular beds of conglomerate and coal. N. H. Darton of the United States Geological Survey in describing the Lakota sandstone in the Edgemont district gives its thickness as 300 feet. E. T. Hancock in his Mule Creek and Lance Creek sections gives the thickness for those districts as 199 feet. Mr. Hancock describes the oil bearing sand in the Mule Creek field as a member of the Lakota formation.

The Lakota sandstone is overlain by the highly colored Fuson shales. The Fuson formation consists of pure shale interstratified with sandy shale and shaly sandstones. The shale varies in color from light and dark gray to purple and maroon. In some localities as in the Edgemont district there is a limestone member occurring between the Lakota sandstone and the Fuson shale, known as the Minnewaste formation. The Fuson formation is of little or no economic importance.

UPPER CRETACEOUS SERIES.

DAKOTA SANDSTONE.

The Dakota sandstone is one of the most persistent formations in the Black Hills region and adjacent territory. In eastern Nebraska the formation consists of soft, buff to brown, friable sandstone interstratified with bluish-gray sandy shales. In the Black Hills region, it is much harder and weathers to a reddish brown, forming pronounced escarpments and "hog backs" where exposed. In the vicinity of Edgemont it is 150 feet thick, and in the Mule Creek and Lance Creek oil fields it is 60 feet thick. It is usually water bearing in Nebraska and South Dakota, but certain formations in Wyoming and Montana, which have been correlated with it are known to be oil bearing.

COLORADO GROUP.

BENTON FORMATION.

The Benton formation includes the Graneros shale, Greenhorn limestone and Carlile shale. The basal member of the group, the Graneros, is composed of dark gray to black shale in the

lower and upper parts of the formation with intervening light-gray sandy shales. It has a total thickness of about 890 feet. The upper 500 to 600 feet contains beds of large concretions which cause this part of the formation to weather, into more or less irregular bench like forms. At New Castle and in the Mule Creek and Lance Creek fields there is a sandstone member in the Graneros located about 175 feet above the base. It varies in thickness from 3 to 50 feet. In the Lance Creek field E. T. Hancock described the New Castle member as consisting of a lower and upper sandstone with an intervening shale member. He gives the thickness of the upper sandstone as 20 feet and the shale member about 15 feet. The New Castle sandstone is the oil bearing member in the Lance Creek, New Castle and Osage fields.

The Graneros shale is conformably overlain by the Greenhorn limestone, which consists of hard gray thin bedded fossiliferous limestone interstratified with less thick beds of gray to buff shales. It is well exposed in one locality on the Chadron, Nebraska, anticline and erodes into a pronounced escarpment. It can be readily identified by the fossil shell *Inoceramus labiatus* which occurs in abundance in the Greenhorn limestone. This formation is of no particular economic importance.

The Greenhorn limestone is overlain by the Carlile shale, the upper member of the Benton group. The formation consists of dark shale with thin beds of shaly sandstone. The upper portion of the Carlile is characterized by large concretions two to three feet in diameter of the septaria type. The concretionary member is well exposed in the Chadron Nebraska anticline. The Carlile varies in thickness from 500 to 700 feet in Eastern Wyoming and Western South Dakota. The Carlile formation contains the Wall Creek sandstone member which is the principal producing sand in the Salt Creek and Big Muddy oil fields. The logs of wells in the Salt Creek field show the thickness of the Wall Creek sandstone to be approximately 125 feet. The upper part of the sand is located according to Weggerman 220 feet below the base of the Niobrara formation.

At a depth of 260 feet below the Wall Creek sand is another oil bearing sand 20 to 25 feet thick and known as the "Lower Wall Creek sand." This sand covers a larger production area than the upper Wall Creek sandstone, and is a heavy producer.

The top of the Colorado group is represented by the Niobrara

limestone. It is composed of gray to buff colored chalky limestones interstratified with thin shale beds. The lower part of the formation contains one shale member approximately 50 feet thick. In the Chadron, Nebraska, anticline the Niobrara forms high escarpments, which weather to a pronounced buff color. It is about 185 feet thick in the Chadron structure. This formation does not contain productive oil and gas sands in any of the fields referred to in this report. Wells which are now being drilled at Wray, Colorado, have encountered gas in a limestone formation which appears to be the Niobrara. These wells have a reported initial production of 1,000,000 to 2,000,000 cubic feet of gas per day. The gas bearing limestone was penetrated at a depth of 1590 feet and reported to be 410 feet thick.

Wray, Colorado, is located 9 miles west of the Nebraska-Colorado line and about 180 miles southeast of the Agate anticline. The log of the Wray, Colorado, well shows that the overlying Pierre shale is from 1,500 to 1,600 feet thick in that district. The top of the Pierre in a part of the region is exposed at the surface. The gas which has been found at Wray, Colorado, is being used by the Mid Fields Oil Company for fuel in drilling additional wells.

CRETACEOUS SYSTEM.

MONTANA GROUP.

PIERRE SHALE.

The basal member of the Montana group is the Pierre shale which immediately overlies the Niobrara limestone. It is composed of dark gray shales with some thin sandstone and sandy shale layers. In the Salt Creek field it contains two prominent sandstone members known as the Shannon and Parkman sandstones. The lower or Shannon sandstone is oil bearing in the Salt Creek field.

The Pierre is approximately 1,200 feet thick in the Edgemont district just north of Sioux County, Nebraska, and 3,300 feet thick in Lance Creek. The log of the Prairie Oil and Gas Company's well drilled in Banner County, Nebraska, shows the Pierre with the overlying Laramie to be 2,831 feet thick in central-western Nebraska. As indicated in this log there are three sandy shale members within the Pierre formation underlying Banner County. The upper one was encountered at a depth of

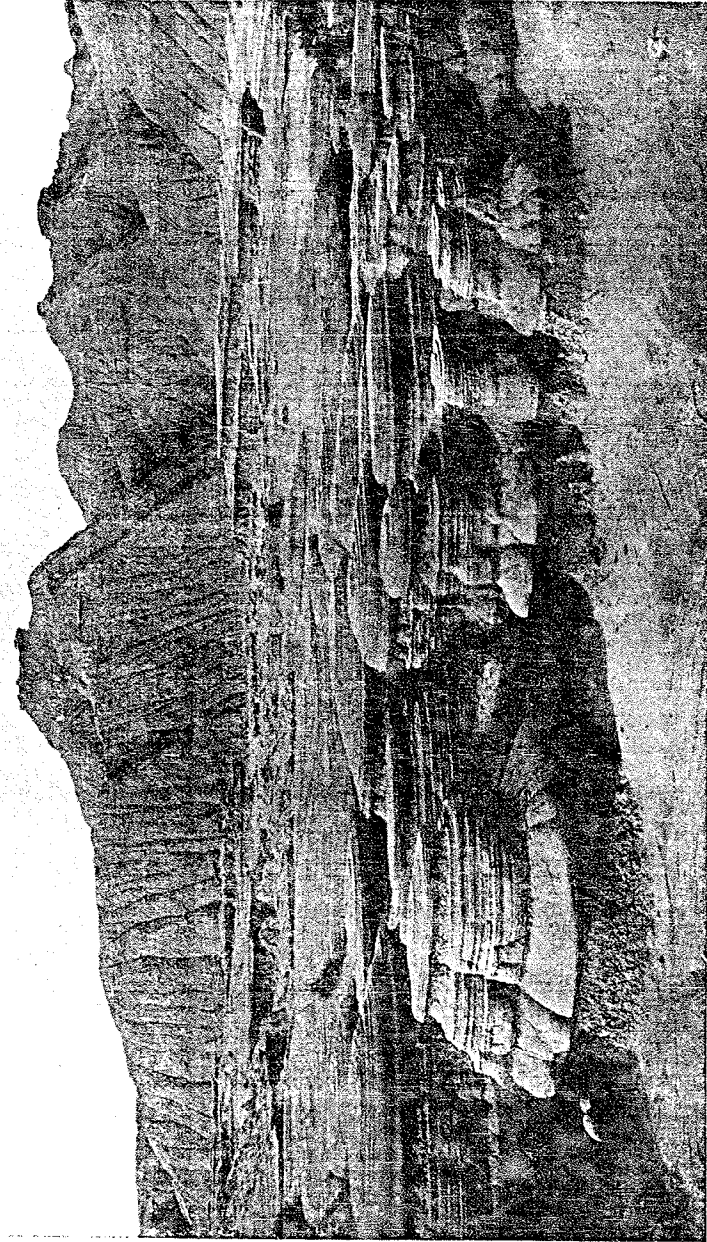
1,850 feet and is 120 feet thick, the second 30 feet thick, at a depth of 2,190 feet and the third 45 feet thick at 3,000 feet. The upper sandy shale member may be the equivalent of the Shannon sandstone. The Shannon member in the Salt Creek field consists of an upper sand 40 feet thick and a lower sand 50 feet thick, separated by 30 or 40 feet of sandy shale. On the Agate structure the Pierre shale will probably be thicker than is given in the Edgemont section to the north, and somewhat less than indicated in the Lance Creek well logs. Near Wray, Colorado, 9 miles west of the Nebraska-Colorado state line, the Pierre shale varies in thickness from 1,500 to 1,600 feet. It is exposed at the surface in places along the Arikaree valley. It thickens again as it approaches the Rocky Mountain uplift. In the Sterling, Colorado, well it is reported to have a thickness of 3,300 feet.

TERTIARY SYSTEM.

OLIGOCENE SERIES.

WHITE RIVER FORMATION.

The White River formation of western Nebraska is composed of the Chadron and Brule clay members. In Nebraska the Chadron consists of a lenticular bed of conglomerate at the base overlain by bluish gray sandy shale. In many places the Chadron member contains numerous veins of chalcedony which have been broken down as the enclosing shale beds are eroded away. The Chadron shales are well exposed in the vicinity of Crawford and Orella, Nebraska. Shallow wells which have been drilled in and near Crawford have penetrated a sand at the base of the Chadron member of the White River formation which is gas bearing. The gas is probably derived from the underlying Pierre shale. Gas producing shallow wells have been reported from Whitney, Nebraska, a station on the Chicago and Northwestern Railway located about 15 miles northeast of Crawford. The following table contains a partial list of the gas producing wells which have been reported from the vicinity of Crawford, Nebraska.



Sand concretions in White River formation, Toadstool Park, Sioux County Bad Lands, near Adelia, Nebraska. Photograph by Dept. of Geology, University of Nebraska.

Gas producing shallow wells located near Crawford, Nebraska.

Location.	Depth in feet.
M. G. Souther ranch—sec. 30, T. 32 N., R. 51 W.....	100
Smith ranch—sec. 32, T. 32 N., R. 51 W.....	100
Stapleton and Coleman well in Crawford, Nebraska.....	257
Hungerford well No. 1 in Crawford, Nebraska.....	325
Hungerford well No. 2 in Crawford, Nebraska.....	427
Buffington well near Crawford, Nebraska.....	80
Well near Whitney, Nebraska.....

A sample of the gas from the Stapleton and Coleman well was analyzed by Dr. Fred W. Upson of the Department of Chemistry, University of Nebraska. In a letter to Mr. Coleman he makes the following report: "We have made a test on the larger sample of gas which you sent and find it very similar to the smaller sample. This sample shows 17.8% Nitrogen and 82.2% Combustible Gas, which upon analysis is proven Methane and identical with the so-called 'Natural-gas.'"

In a letter to the Department of Geology, University of Nebraska dated November 24th, 1920, Mr. W. H. Coleman gives the following description of the Stapleton-Coleman gas well: "I am sending to the department by today's mail a jar of water and one of gas taken from the Stapleton-Coleman artesian and gas well, which was struck here March 2nd, 1920, and which has flowed gas and water ever since. The 'eruption' which followed the penetration of the cap rock sent mud and water to a height of 65 to 70 feet for 3 hours, after which it gradually lowered. After the water had gone down the gas was lighted and burned so briskly that the drillers had considerable difficulty in putting out the fire. In resuming drilling operations we found that 30 feet of the hole had been filled with sand and when we reached the old depth the eruption was repeated with somewhat diminished force. After securing casing we finally succeeded in going down from the gas depth of 257 feet to 286 feet, where we were forced to abandon the well because of a crooked hole."

"The surface elevation of the well is 3,755 feet above sea level. We had been drilling in a greenish colored clay when we struck the greenish sand which was gas and water bearing. Some *Titonotherium* bones were found. There is no doubt but that we struck the Chadron formation."

In another letter to the writer under date of June 25th, 1921, Mr. Coleman says: "A number of wells have been drilled in the vicinity of Crawford in which gas pockets have been reported

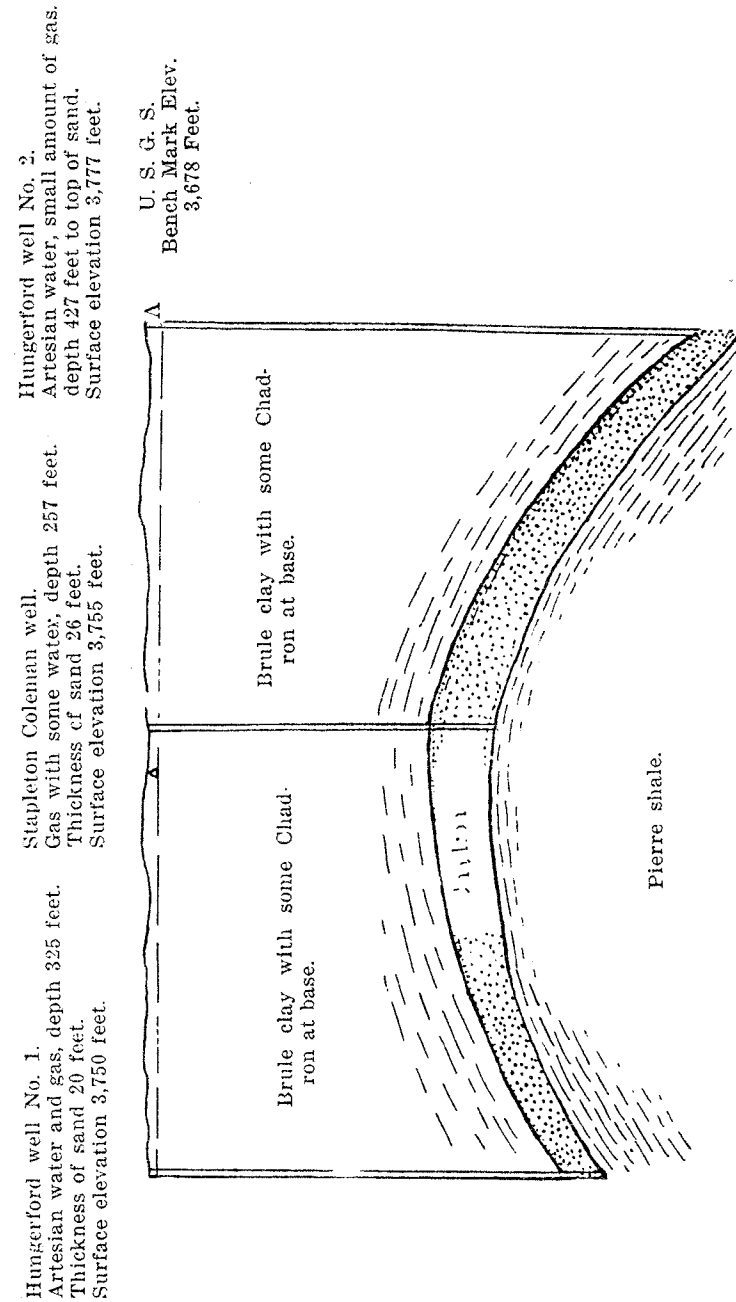
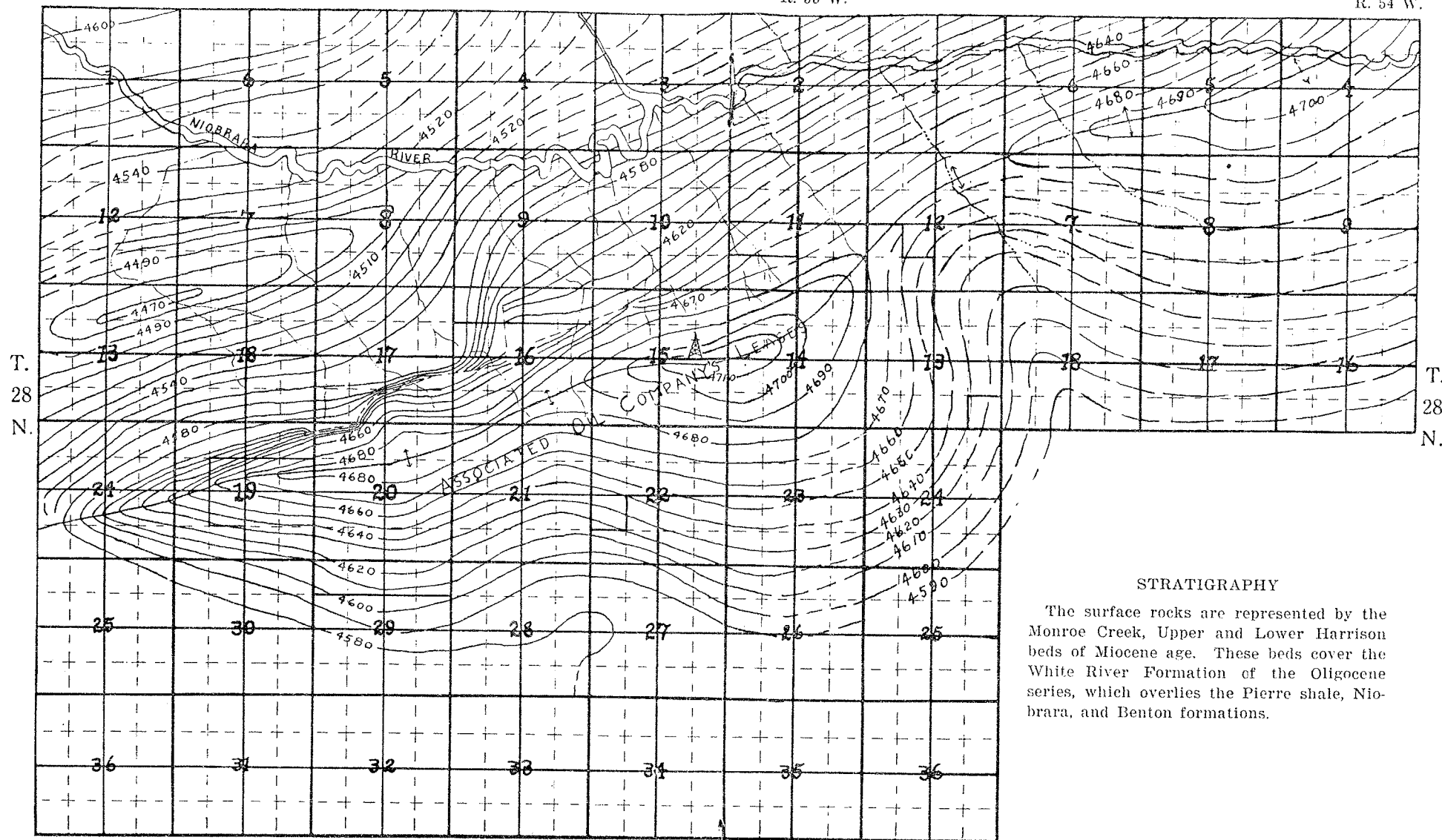


Fig 2.—Structure of the Chadron sand as indicated by the gas bearing wells drilled in Crawford, Nebraska.
The distance from Hungerford well No. 1. to Hungerford well No. 2, is 6,285 feet. Horizontal scale, 1 inch = 1400 feet. Vertical scale, 1 inch = 140 feet. (Approximately.)

Data for sketch, furnished by W. H. Coleman.



STRATIGRAPHY

The surface rocks are represented by the Monroe Creek, Upper and Lower Harrison beds of Miocene age. These beds cover the White River Formation of the Oligocene series, which overlies the Pierre shale, Niobrara, and Benton formations.

Structural contour map of the Agate Anticline, Sioux County, Nebraska.

By E. F. Schramm, H. J. Cook.

Scale approximately 1 inch to the mile.



but only three have had any degree of permanency. The first one was drilled on the ranch of Mrs. M. G. Souther, located six miles northeast of Crawford. The second one is located on the farm of Clyde Buffington, about one mile southeast of the Souther well. The third was drilled by Stapleton and Coleman while prospecting for artesian water in the city of Crawford. The latter has produced a small amount of gas for sixteen months. The gas from all of the wells will burn. The stratigraphical evidence we have been able to find leads to the conclusion that these three wells are located on a structural high."

The structure of the gas bearing sand in the Chadron formation as it occurs in Crawford, Nebraska, is illustrated by a sketch included in this report. Since the gas bearing sand immediately overlies the dark carbonaceous shale of the Pierre formation it is the logical presumption that these shales are the source of the gas.

The Chadron member is overlain by the Brule clay which is composed of a pale buff or flesh-colored sandy clay with bands of volcanic ash near the top. It underlies a large part of western Nebraska and has a thickness varying from 500 to 600 feet. The total thickness of the White River formation (Chadron and Brule) as shown by the log of the Agate well is approximately 805 feet.

EXPOSED ROCKS.

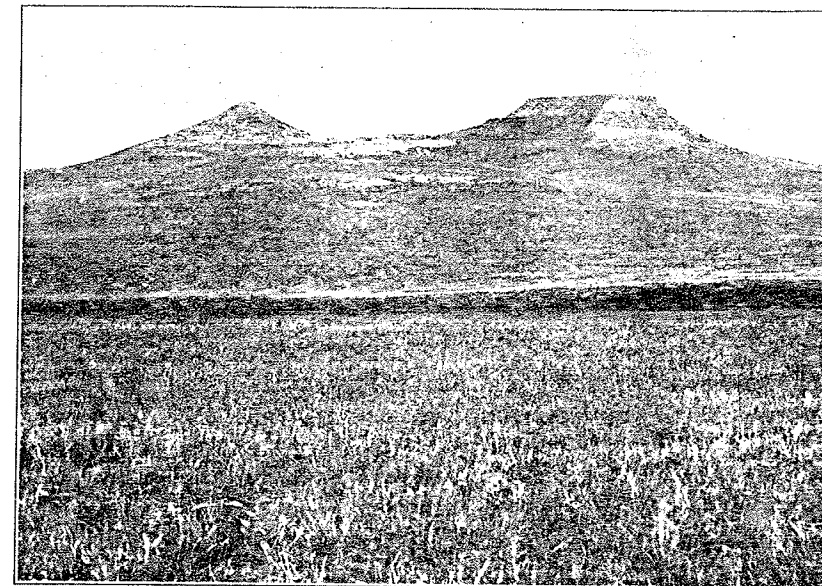
TERTIARY SYSTEM.

MIOCENE SERIES.

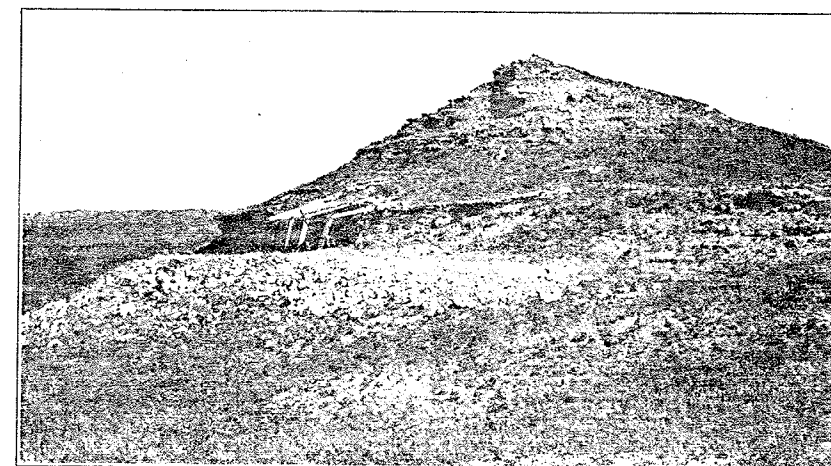
The exposed formations on the Agate structure consist of the Monroe Creek beds, Lower and Upper Harrison. The basal member of the series, the Monroe Creek beds, is composed of pale ochre to buff colored, somewhat argillaceous sandstone interstratified with clay. The beds are characterized by irregular and nodular shaped concretions which usually occur at right angles to the bedding planes. The Monroe Creek is well exposed along the north limb of the Agate anticline and is approximately 300 feet thick in western Nebraska. The Monroe Creek may be correlated in part with the Rosebud formation of South Dakota. Like the overlying Harrison formation it contains fossil bones of a considerable number of species of Tertiary animals. It is 200 feet thick in the vicinity of Agate.

U.

C.



The Lower Harrison beds as exposed in the Agate Springs Fossil quarries. U., University Hill; C, Carnegie Hill. Niobrara valley in the foreground.



Detail of Lower Harrison beds as exposed in University Hill, on the north limb of the Agate anticline. (Above photographs from the collection of the Dept. of Geology, University of Nebraska.)



A panel of fossil bones from University Hill, Agate Springs fossil quarry, Sioux County, Nebraska. Size $3\frac{1}{2}$ by $5\frac{1}{2}$ feet. Parts of the following animals are represented: Rhinoceros, *Dicceratherium arkarense*; *Moropus cooki* and *parvus*; and the giant hog, *Mastodons*. Four panels similar to above were collected for the State Museum by E. G. Davis, P. R. Butler and E. F. Schramm under the direction of E. H. Barbour. From Charles H. Morrill collection, Department of Geology, University of Nebraska.

(24)

The Lower Harrison member of the Arikaree formation overlies the Monroe Creek beds. It is composed of a gray friable calcareous sandstone. The sandstone contains some clay as local lenses. The Lower Harrison varies in thickness in Sioux County according to Cook from 40 to 300 feet. It is characterized by numerous concretions, fossil bones and large spirals or corkscrews known as *Daemonelix*. Many of these spirals are 10 to 15 feet in length and over a foot in diameter. They occur in abundance in the central part of the Lower Harrison and have been described by Barbour, who calls this phase of the Harrison member, the "Daemonelix beds."

About 60 feet below the top of the Lower Harrison beds is a prolific fossil bearing horizon about 3 feet thick which has been traced by Cook and others for a number of miles in the vicinity of Agate. This horizon contains the widely known Agate Springs fossil quarries.

Overlying the Lower Harrison is a gray to buff colored series of coarse and fine sandstone interstratified with thin sandy clay strata which combined, form the Upper Harrison member of the Arikaree formation. It is prominently exposed between the White and Niobrara Rivers and extends for a considerable distance south of the Niobrara. It has a normal thickness of about 200 feet. This member contains considerable fine grained limy sandstone which in places changes on the strike of the beds to coarse sand and gravel. The texture of the beds and the general lithologic characteristics indicate that the sediments have been deposited in flood-plains, or shallow basins. The Upper Harrison is also noted for the large number of fossil remains of Cenozoic animals, which it contains. Aside from their importance as fossil bearing horizons, the Monroe Creek, Lower and Upper Harrison are of little economic importance.

LOGS OF WELLS.

The log of the well which is now being drilled by the Associated Oil Company upon the Agate anticline shows that the following formations have been penetrated. The well is located on the side of a deep ravine in the south-central part of the NE. $\frac{1}{4}$ of sec. 15, T. 28 N., R. 55 W., and geologically below the Upper and Lower Harrison formations.

Log of Cook well No. 1 Associated Oil Company in the NE. ¼ sec. 15, T. 28 N., R. 55 W. Agate, Sioux County, Nebraska.

Driller's interpretation.	Thick-ness.	Depth.
	Feet.	Feet.
Yellow clay.....	100	100
Yellow clay with small amount of sand.....	40	140
White River formation (yellow clay).....	470	610
White River formation with a little gravel.....	115	725
Yellow clay with streaks of blue clay.....	20	745
Sticky yellow clay.....	100	845
Pierre shale (very sticky blue clay).....	145	990
Pierre shale (blue).....	140	1,130
Pierre shale contained a small amount of iron pyrite and a small showing of oil.....	20	1,150
Pierre shale.....	719	1,869
Shell.....	2	1,871
Pierre shale with sea shells at 1960.....	24	1,895
Pierre shale.....	370	2,265

Landed 20 inch casing at 197 feet and 10 inches, from the floor. The hole contains 185 feet and 10 inches of 20 inch casing. Landed 15½ inch casing at 968 feet and 8 inches, from the floor. There are 953 feet and 10 inches of 15½ inch casing in the hole. Landed 12½ inch casing at 2,007 feet.

Harold J. Cook, resident geologist for the Associated Oil Company, made a microscopic examination of all the cuttings as they came from the well and he gives the following description and interpretation of the log of Cook well No. 1:

H. J. Cook's interpretation.	Thick-ness.	Depth.
	Feet.	Feet.
Quaternary: Soil and sand, sandy lime and gravel, consisting more or less of surface wash.....	40	40
Monroe Creek Beds: Flesh colored to buff and brown sandy clays, with water at 140 feet in rather thin fine sand with some silt.....	100	140
White River formation, (Brule and Chadron): Brule clay, flesh colored, no pure sand encountered.....	470	610
Brule clay, with increasing amounts of chalcedony. Thin bed of sandy gravel at 710 feet.....	100	710
Creamy-white clay interbedded with thin blue layers. Probably represents the Upper part of the Chadron member.....	15	725
Chadron formation: Typical Chadron clay, consisting of bluish gray sandy clay	80	805
Sticky clay (contact of Chadron and Pierre formations).....	5	810
Pierre Formation: Yellowish stained Pierre clay, very sticky, no sand, this represents a part of the Upper oxidized member of the Pierre known as the "Rusty member" or the Ainsworth formation.....	35	845
Yellowish stained Pierre shale, very light yellow with streaks of blue mud. A microscopic examination of this material showed a predominance of very fine clays and silt, with a small amount of finely reduced quartz and other minerals. The entire section through the lower part of the Chadron member and the Upper 150 feet of the Pierre shale reduces under the drill to a very sticky gummy mud, which caves readily and would not stand up in the hole, without heavy water pressure.....	10	855
Typical bluish-gray Pierre shale.....	220	1,075

Cook well No. 1.—Continued.

H. J. Cook's interpretation.	Thick-ness.	Depth.
	Feet.	Feet.
Bluish-gray Pierre shale interstratified occasionally with very thin shaly sandstones, called "shells" by the drillers. The shale showed an increasing amount of organic matter. From approximately 1,200 feet down to 1,460 feet there was a pronounced showing of oil "rainbows" upon the slush pit. At 1,460 feet a few thin very fine grained argillaceous sandy layers were encountered which gave a showing of oil. The sediments which were recovered from the 1,460 foot level, when thoroughly washed with cold water gave wide continuous oil rainbows. Streaks of light brown oil ran down the stem and bit and on the outside of the bailer when these tools were pulled from the hole.....	1,190	2,265

The following logs of deep wells which have been drilled in western Nebraska and in adjoining states near the Nebraska state line, are given for the purpose of comparison, and interpretation of the formations penetrated by the drill.

Log of John Kelly well No. 1, Prairie Oil and Gas Co., in sec. 33, T. 19 N., R. 55 W., Banner County, Nebraska.

Location made September 20, 1917—250 feet from north line, 5,030 feet from the south line, 250 feet from the east line, 5,030 feet from the west line of the section. Drilling commenced December 3, 1917. Drilling completed April 21, 1919. Total depth of well 5,697 feet. Dry hole. Temperature 150 degrees at 4,250 feet, 194 degrees at 5,460 feet. Drillers' interpretation of strata and E. F. Schramm's correlation. This well was not located upon a structure favorable for the accumulation of oil and gas.

Log of John Kelly well No. 1 Prairie Oil and Gas Co., in sec. 33, T. 19 N., R. 55 W. Banner County, Nebraska.

Nature of Strata.	Color.	Hard or Soft.	Thick-ness.	Total Depth.	Remarks.
Surface			8	8	
Loose sand			22	30	
White River Group, Brule and Chadron:					
Hard pan	Yellow		370	400	{ Little Water at 65 feet.
Shale	Blue		65	465	
Mud	Yellow		10	475	
Mud	Blue		20	495	
Shale	Light blue		25	520	
Sandy shale			10	530	
Laramie:					
Mud	Yellow		15	545	
Shale	Blue		85	630	
Shale	Black	Hard	10	640	
Shale	Brown		175	815	{ Water at 720 feet, 100 bbis.
Water, sand			20	835	{ Water level, 105 feet.

Log of John Kelly well No. 1 Prairie Oil and Gas Co., in sec. 33, T. 19 N., R. 35 W. Banner County, Nebraska.—Continued.

Nature of Strata.	Color.	Hard or Soft.	Thick-ness.	Total Depth.	Remarks.
Pierre Shale:					
Shale	Brown		25	860	
Sticky clay	Blue		60	920	
Shale	Brown		60	980	
Shale	Dark blue		570	1,550	Stands up.
Shale	Dark blue		70	1,620	Very cavey.
Shale	Gray		160	1,780	Very cavey.
Shale	Blue		70	1,850	
Sandy shale	Light gray		120	1,970	
Shale	Dark gray		40	2,010	
Shell			3	2,013	
Shale	Dark		177	2,190	
Sandy shale			30	2,220	
Shale	Dark		70	2,290	
Sandy shale			180	2,470	
Shell		Hard	3	2,473	
Shale	Dark	Soft	347	2,820	
Shale	Dark		80	3,000	Streaks of sand.
Sandy shale			45	3,045	
Shale	Dark		416	3,461	
Niobrara limestone:					
Shell		Hard	1	3,462	
Lime shale	Dark gray	Nebr. lime	263	3,725	
Benton formation, Carille shale:					
Shale	Light brown		100	3,825	
Sandy shale	Dark gray	Hard	115	3,940	
Shale	Dark blue	Hard streaks	120	4,160	Cavey
Shale	Light blue	Hard streaks	415	4,775	Cavey
Shale	Light blue	Hard streaks	25	4,600	{ Mixed with } white shale.
Shale		Hard	3	4,603	
Shale	Dark brown		257	4,860	
Slate			190	5,050	
Benton formation, Greenhorn limestone:					
Lime			30	5,080	
Lime and broken shale			10	5,090	
Lime			45	5,135	
Benton formation, Graneros:					
Shale	Black		15	5,150	{ Burns like } oil shale.
Shale	Blue	Soft	10	5,160	
Sand		Hard-fine	10	5,170	
Lime		Hard	30	5,200	
Shale	Light blue		80	5,280	
Slate		Hard streaks	70	5,350	
Lime shale			95	5,445	
Shell			5	5,450	Pyrite of iron.
Shale	Brown		105	5,555	White particles.
Shale or Bentonite	White		5	5,560	
Shale	Brown		5	5,565	
Shale	Brown		10	5,575	
Shale or Bentonite	White		20	5,595	
Shale	Dark	Soft	67	5,662	
Shell		Hard	1	5,663	Pyrite of iron.
Sand	Black		14	5,677	
Shale	Brown	Soft	20	5,697	No grit.

Log of well No. 2, The Midfields Oil Co., in the NE. ¼ sec. 17 T. 2 S., R. 43 W. Yuma County, Colorado. 9 miles west Nebraska state line.

E. F. Schramm's interpretation of formations.	Thick-ness.	Depth. Feet.
Ogalalla formation: Gray sandy clay and limy sandstone.....	10	10
Pierre formation: Bluish gray shale, interstratified with thin sandy, limy shale members in the lower part.....	1,580	1,590
Niobrara formation: Limestone interstratified with cream colored limy shales, gas bearing. This well was plugged to 1,710 feet and is producing at the present time between one and two million cubic feet of gas per day.....	390	1,980

The detailed log of well No. 1, drilled to a depth of 3,620 feet by the Midfields Oil Company was not available. Geo. E. Retter, general superintendent for the Company, stated that "Red beds" were encountered at a depth of 2,845 feet and continued to the bottom of the hole which was 3,620 feet deep. An oil bearing sand 52 feet thick was penetrated at a depth of 2,400 feet. Coal beds were reported at 2,560 feet. The coal bed horizon probably represents the Lakota formation.

Log of well No. 1, Clear Oil Co., in the NW. ¼ sec. 33, T. 35 N., R. 47 W. Dawes County, Nebraska. Drilling begun Oct. 25, 1919. Completed April 2nd, 1920.

Driller's interpretation of strata.	Thick-ness.	Depth.
E. F. Schramm's correlation.		
Benton formation:	Feet.	Feet.
Dark hard soil.....	4	4
Brown hard shale.....	3	7
Brown soft shale.....	13	20
White hard lime.....	4	24
Dark soft shale.....	26	50
White soft shale.....	60	110
Dark soft shale.....	250	360
Gray soft sand.....	5	365
Gray soft shale.....	60	425
Gray soft sand.....	65	470
Gray shale, caved badly.....	150	620
Dark soft shale.....	195	815
Gray soft shale.....	97	912
Gray hard sand, water, but not enough to drill with.....	5	917
Gray soft shale.....	6	923
Gray soft shale mixed with sand.....	10	933
Arsenical iron, water 300 feet in hole.....	5	938
Gray soft broken sand.....	12	950
White soft clay.....	45	995
Red hard rock gritty.....	5	1,000
Blue soft shale.....	5	1,005
Gray soft broken sand.....	5	1,010
Blue soft shale.....	5	1,015
Dakota sandstone: Gray sand, water 400 feet in hole.....	103	1,118
Fuson and Lakota formations:		
White talc.....	6	1,124
Red rock.....	12	1,136
Blue shale.....	34	1,170
Gray sand, water 500 feet.....	5	1,175
Blue shale.....	15	1,190
Gray to brown sand (showing of oil).....	88	1,278
Blue soft shale.....	5	1,283
White soft sand.....	17	1,300

In this well a showing of oil was obtained from the Lakota sandstone but when this formation was penetrated the hole was carrying 600 feet of water. Under such conditions, the showing obtained was considered encouraging. This well was drilled on one of the minor folds of the Chadron anticline.

The well logs which have been quoted in this report are given for the purpose of showing the approximate thickness of the various Cretaceous formations underlying western Nebraska.

Of the formations encountered in the preceding well logs, the Pierre, Benton, Dakota and Lakota are known to be oil or gas bearing in certain fields in Colorado, Wyoming and Montana. Most of the larger oil fields in Wyoming are recovering oil from "sands" in the Benton formation. The Wall Creek sand in the Salt Creek and Big Muddy fields in Wyoming occurs within the Benton formation or within shale members which can be correlated with the Benton. The underlying Dakota formation in the Black Hills region is usually water bearing, but is known to be oil bearing in a few localities. The Benton is overlain by the Niobrara limestone, which is gas bearing at Wray, Colorado.

STRUCTURE.

SALIENT FEATURES.

East of the Rocky Mountain front range and the Hartville uplift in the High Plains region there are a series of minor folds extending from southeastern Colorado to the Black Hills uplift. The long anticline extending through Cheyenne County, Colorado, the Yuma County, Colorado structure, Goshen Hole, Wyoming, Agate and Chadron, Nebraska structures, may be mentioned as types. These anticlines are designated as "Tertiary structures" because the youngest rocks exposed on each flexure belong to the Tertiary system. None of them have been mapped and described in detail. They have presumably been overlooked or ignored by geologists because of the major unconformity existing between the Tertiary sediments and the underlying oil bearing Cretaceous rocks. The structures are characterized by low dips varying from 1 to 8 degrees. Other pronounced structures of note which occur in the same general region between the Hartville uplift and the Black Hills are the Old Woman Creek, Lance Creek and Mule Creek anticlines. In these anticlines which are oil bearing, the Cretaceous rocks are exposed at the surface.

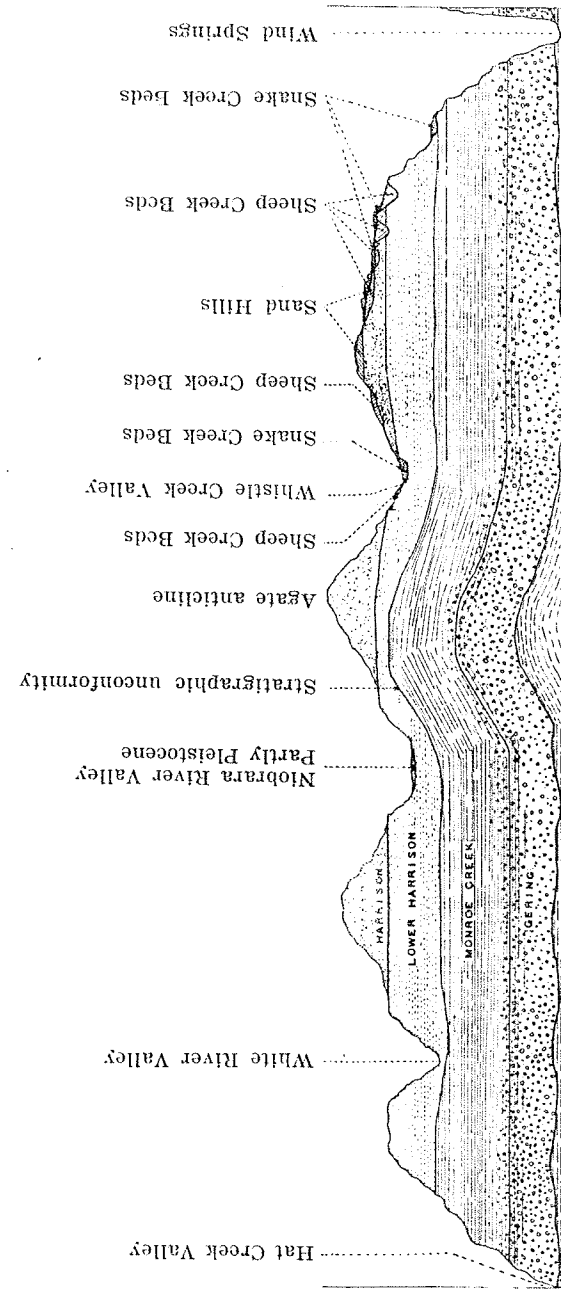


Fig. 3.—A section from Hat Creek south through Sioux County to Wind Springs, a distance of approximately 50 miles, showing folding of strata south of the Niobrara River in the vicinity of Agate, Nebraska. Vertical exaggeration approximately fifty-fold. (After H. J. Cook Volume 7, Part II, page 63, Nebraska Geological Survey.)

The diastrophic movements which brought the rocks of the Hartville uplift, Rawhide Butte, and the Black Hills to the surface also produced the minor folds above mentioned.

STRUCTURE OF THE AGATE ANTICLINE.

The Agate anticline is an elongated structure approximately 12 miles long and from 2 to 3 miles wide extending from sec. 24, T. 28 N., R. 56 W., to sec. 35, T. 29 N., R. 54 W. It has a north-east-southwest trend with the high, or dome area in sections 14 and 15, T. 28 N., R. 55 W.

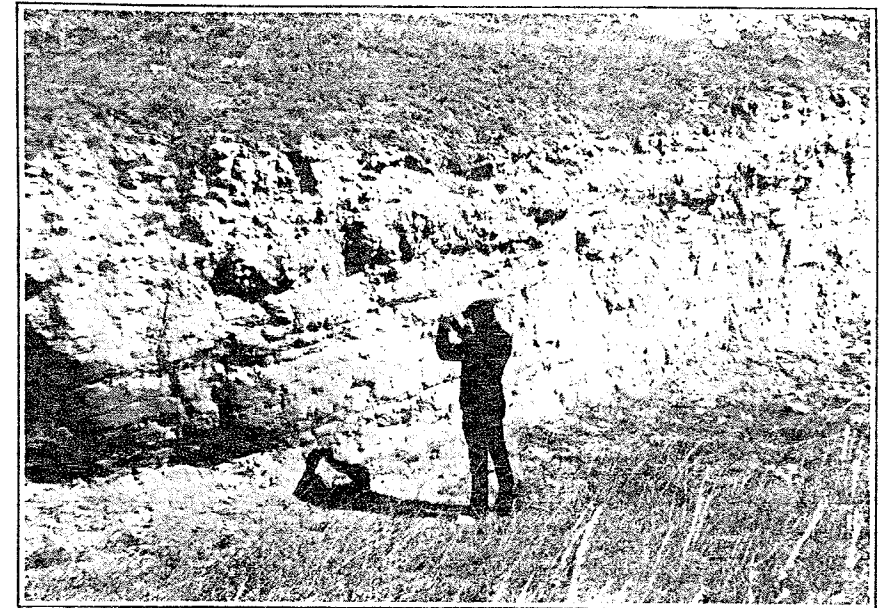
Clinometer readings taken in section 15 on the north limb of the structure showed the Monroe Creek beds dipping to the northwest at an angle of 7 to 8 degrees. Dip readings taken at various places upon the structure show a variation from 2 to 8 degrees. The most pronounced dips occur on the north limb of the structure. The structural contours vary from 4,470 on the axis of the syncline to 4,710 feet on the uppermost closing contour of the anticline.

The axis of the anticline passes through sec. 24, T. 28 N., R. 56 W., and secs. 19, 20, 21, 16, 15, 14, 11 and 12, T. 28 N., R. 55 W. and secs. 6, 5, and 4, T. 28 N., R. 54 W.

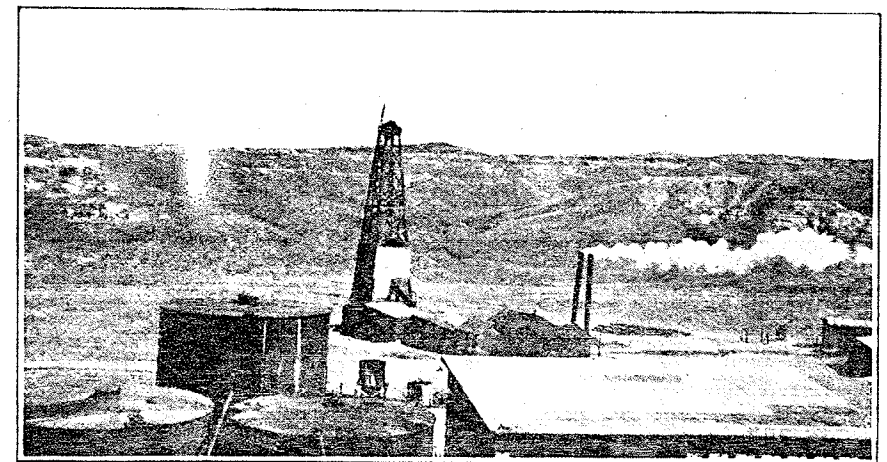
A study of the exposed rocks in the Agate anticline reveals two distinct periods of local flexing. The Lower Harrison beds were deposited upon the folded and partially truncated strata of the Monroe Creek member of the Arikaree formation.

Harold J. Cook, who has spent several years in a detailed study of the formations and their fauna, of this region has described in considerable detail the folding of the Tertiary rocks on and in the vicinity of the Agate anticline. In volume 7, part II, of the Nebraska Geological Survey Mr. Cook describes the Tertiary folds of Central Sioux County as follows:

"About one fourth of a mile south of the Agate Spring Quarries, there suddenly appears a series of strata, lithologically and stratigraphically identical to the Monroe Creek beds. These rise quite abruptly to a little above the present level of the quarries. South of the quarries, these beds show a somewhat eroded face, upon which is deposited the Lower Harrison, thus indicating a considerable lapse of time between the deposition of these two formations. The evidence from well borings and other sources would seem to indicate that these beds dipped sharply to the north two hundred to three hundred feet, in the vicinity of the Niobrara valley. They stand out in a rather sharp point one mile southwest of the Agate Spring Quarry, run diagonally east about one mile, then curve to the northeast.



Monroe Creek beds dipping at an angle of 7 degrees on the north limb of the Agate anticline, in sec. 10, T. 28 N., R. 55 W.



Associated Oil Company's rig showing water tank house and fuel oil tanks in the foreground. Monroe Creek, Upper and Lower Harrison beds shown in the background. Sec. 15, T. 28 N., R. 55 W.

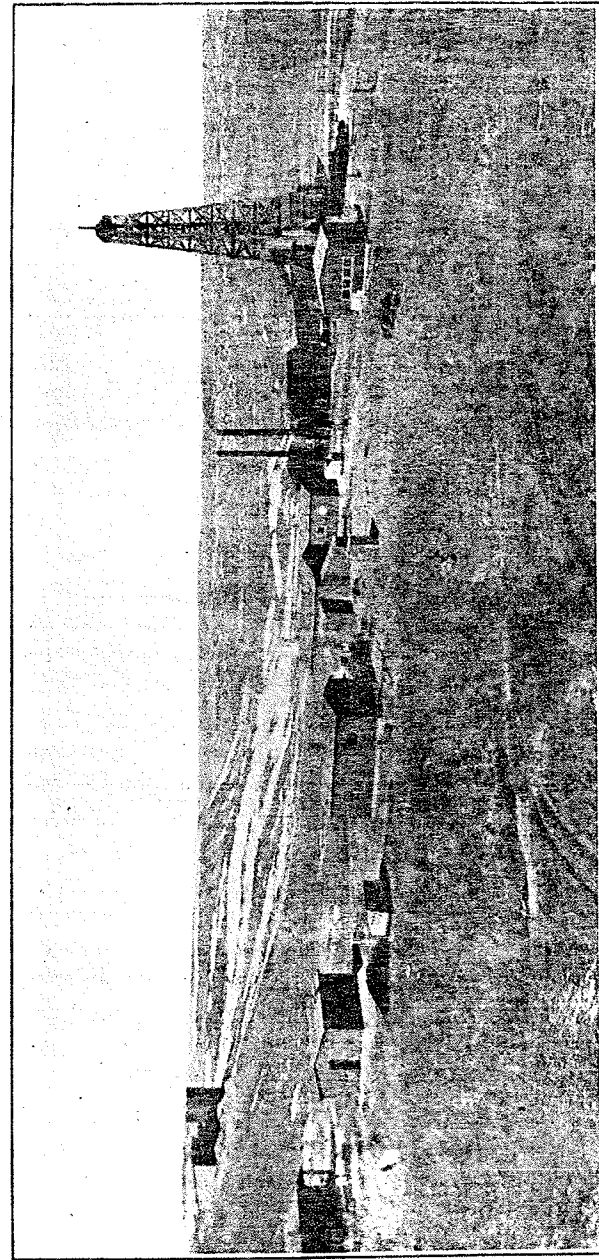
crossing the Niobrara valley about four miles east of the quarries, and continue northeast."

"These beds were evidently thrust up prior to the deposition of the Lower Harrison beds. While the Lower Harrison beds were being deposited, this uplift formed a highland area of considerable extent in the region to the south and east of the Agate Spring Quarries. About a mile southeast of the Agate Spring Quarries is a synclinal basin in this "Monroe Creek" uplift, with a relatively low anticlinal ridge on the north and northeast. This ridge separated the synclinal basin from the lowlands to the north, during most of the period in which the Lower Harrison was built up. During the periodic floods which deposited the Lower Harrison beds, this ridge, acting as a barrier, formed a lake or lagoon of comparatively still water, as stratified rocks in this area would indicate. This syncline is nearly a mile in extent, and its greatest depression from the top of the surrounding "Monroe Creek" beds is nearly one hundred feet. Near the bottom of this depression is a large bed of volcanic ash and calcium carbonate, two to six feet thick, and several acres in extent. On this is deposited about ninety feet of very fine-grained sandstone to a large degree an acolian deposit, frequently smoothed and settled by comparatively still water, which at times collected in this basin. As its character would indicate, this deposit was principally derived from the sands of the Lower Harrison flood-plains deposits, which were then being laid down on the other side of the narrow barrier formed by the northern rim of the syncline."

"Beginning approximately three miles west of the Agate Spring Quarries occurs a V-shaped uplift in the Lower Harrison beds. This strikes the Niobrara valley approximately at the quarries and parallels the valley on the south an undetermined distance eastward. This uplift is about three miles wide at the quarries, and is most sharply defined at its western extremity, the point of the V, where the fault is about one hundred feet in extent. This uplift evidently occurred between the deposition of the Lower Harrison, and the deposition of the Upper Harrison, as the relation of the strata in these beds at this point clearly shows. Considerable erosion took place on this uplift before the upper beds were deposited. This uplift occurred on nearly the same axis as the "Monroe Creek" uplift, but extended about two miles farther west, and was much more restricted to the east."

Because of the major unconformity which exists between the Cretaceous and overlying Tertiary rocks it is not known whether the underlying Pierre shale, conforms in general structure to the flexures which exist in the Monroe Creek and Harrison beds.

In the Chadron anticline the bordering Tertiary rocks conform in general to the structure of the exposed Cretaceous sediments. If a pronounced divergent structure such as a broad syncline or a centroclinal fold existed in the Pierre shale, in the region of the Agate anticline prior to the deposition of the Tertiary sediments, later local movements sufficient to produce an anticline of low dips in the overlying younger strata, would have



Associated Oil Company's camp on the Agate anticline in sec. 15, T. 28 N., R. 55 W.

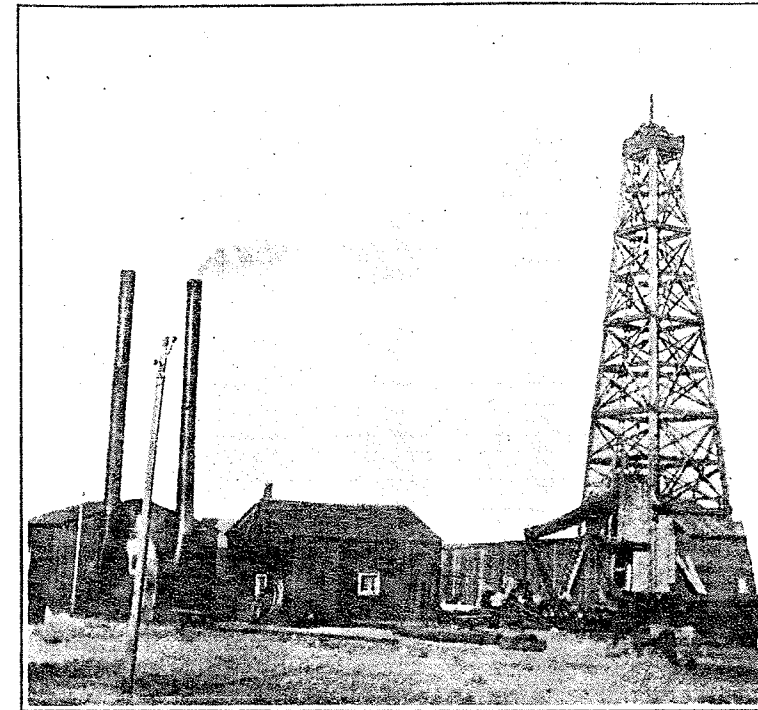
the effect only of slightly flattening the more pronounced syncline in the Pierre shale. It would not entirely obliterate the synclinal structure unless the Tertiary flexures were decidedly pronounced. It is possible that the condition just described exists in the Agate anticline. The fact that this is not the case in a number of Tertiary structures in this general region, lessens the probability of it representing the structural conditions in the Agate anticline. It is only recently that geologists have given Tertiary structures in the Great Plains region serious consideration. The Agate structure is sufficiently broad to be productive over a wide area, provided productive sands are encountered in the Pierre, Benton, or Lakota formations. If the Cretaceous sediments in this region are similar in thickness to those encountered in the Banner County well, it will necessitate a very deep test in order to reach the underlying Dakota and Lakota formations.

SANDS.

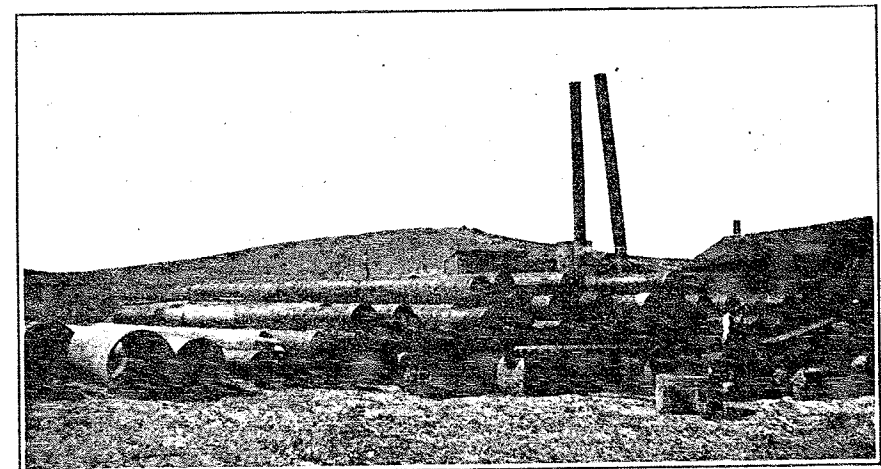
In Colorado the Pierre shale is producing oil from the Hygiene sands, and in Wyoming from the Shannon sand. In Wyoming the Benton formation is producing oil from the Upper and Lower Wall Creek sands and from the New Castle sand. Throughout most of Nebraska, South Dakota and Wyoming the Dakota formation which consists principally of sandstone is known to be water bearing although a formation which may be correlated with it, the Greybull, is oil bearing in one or two localities in Wyoming. A formation in Montana, the Kootenai, which can in part be correlated with the Dakota, is oil bearing in that State. The Wall Creek sand varies from 20 to 150 feet in thickness in Wyoming and is the most constant and prolific producer in the State. If any of the sands mentioned above occur within the formations described and underlying the Agate anticline, they are likely to be productive provided the Cretaceous rocks conform in structure to the overlying Tertiary beds. It is simply a question of their presence or absence within favorable structure and nothing but the drill can give us this information. The Niobrara formation which occurs between the Benton and Pierre formations is gas bearing at Wray, Colorado.

DEVELOPMENT.

The Associated Oil Company of Wyoming, which is said to be a subsidiary of the Southern Pacific Railroad Company, is now



Near view of Associated Oil Company's rig and boiler house. Sec. 15, T. 28 N., R. 55 W.



A view of part of the casing used by the Associated Oil Company in the Agate well.

drilling a test well upon the Agate anticline. The location is in sec. 15, T. 28 N., R. 55 W.

Before beginning drilling operations this company spent considerable time in checking the structural map of this anticline made by E. F. Schramm and Harold J. Cook. The geological work of the Associated Company is directed by Mr. Taff, formerly of the United States Geological Survey, and now head of the Geological department of the Southern Pacific Railroad. Mr. Christian Vrang checked the Agate structure for the Associated Oil Company.

The Associated Oil Company spent approximately seventy-five thousand dollars in equipment and improvements before beginning drilling operations. They have one of the best equipped rigs and camps in the entire country. They have laid a double water line 4 to 5 feet below the surface from the well to the Niobrara valley, a distance of approximately one and a half miles. They have dug a large water well in the Niobrara valley, about 15 feet square, which has been heavily cribbed and equipped with duplicate engines and pumps to handle the water.

The rig is equipped with new tools throughout, a heavy engine, and two 60 horse power boilers all enclosed. They have erected nine buildings, including the boiler and engine houses, and have a battery of eleven 100 to 200 barrel tanks for fuel oil and water. The heaviest of casing has been purchased for this well. A twenty-inch hole was started so that drilling may be continued to the depth of 4,500 feet, if necessary.

The improvements are so complete in every particular that drilling may be continued during the coldest weather without the usual delays and inconveniences which frequently occur during extremely cold weather.

KANOKA PETROLEUM COMPANY

CLINTON R. LEE, President

GEOLOGICAL DEPARTMENT

BULLETIN--A

THE AGATE ANTICLINE
SIOUX COUNTY, NEBRASKA

BY

E. F. SCHRAMM

H. J. COOK



LINCOLN, NEBRASKA

July, 1921