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OIL AND GAS IN OKLAHOMA

NOWATA AND CRAIG COUNTIES

By
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FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19 part 2 entitled, "Petroleum and Natural Gas in Oklahoma." This volume was so popular that the supply was soon exhausted, and for several years copies have not been obtainable.

The present director has seen the need of a revision of this bulletin. On account of lack of appropriations he has not been able to employ sufficient help to compile the data, and has called on some twenty representative geologists throughout the state to aid in the preparation of reports on separate counties. These gentlemen, all busy men, have contributed freely of their time and information in the preparation of these reports.

It will be understood that the facts as set forth in the various reports represent the observation and opinion of the different men. The Oklahoma Gological Survey has every confidence in judgment of the various authors, but at the same time the Survey does not stand sponsor for all statements made or for all conclusions drawn. Reports of this kind are, at best, progress reports, representing the best information obtainable as of the date issued and doubtless new data will cause many changes in our present ideas.

Dr. Edward Bloesch, the author of this report on Nowata and Craig counties has been in touch with the oil and gas development of this area for a number of years. To get additional data for this report he spent some time in the field so that the data contained herein represents the most up to date information available.

June, 1928.

CHAS. N. GOULD,
Director.

OIL AND GAS IN OKLAHOMA

NOWATA AND CRAIG COUNTIES

INTRODUCTION

The writer has done geological work in Nowata and Craig counties occasionally for years, altogether probably more than any other geologist. Even so, he is aware that he was none too familiar with the details of the petroleum geology of these counties. All recent publications on this area were consulted and the well logs published by the Corporation Commission were used. It was found necessary to make a number of field trips in order to straighten out dubious points, but only a limited amount of time could be devoted to field work. It will be seen that detailed observations can be given in some localities while other chapters are very generalized, but it is hoped that this publication is going to be of some benefit to people interested in the geology and in the oil and gas resources of Nowata and Craig counties.

The writer expresses his thanks to his assistant G. G. Senftleben for help in compiling the report and to Chas. N. Gould, Luther H. White, W. J. Sherry, and a number of others for helpful suggestions.

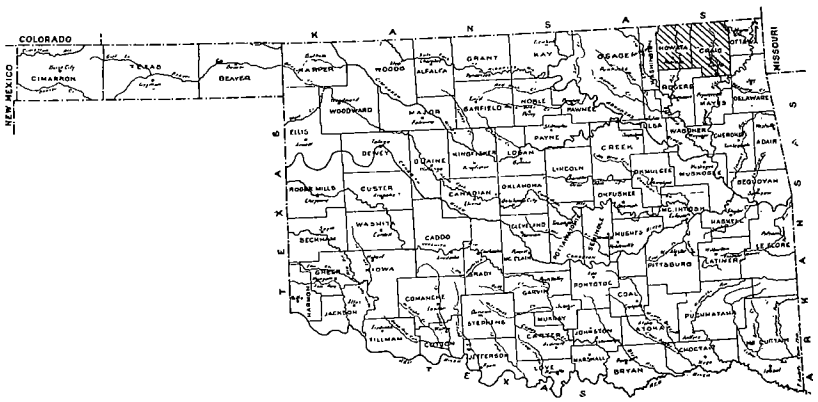

Figure 1. Index map of Oklahoma showing location of Nowata and Craig counties.

NOWATA COUNTY

Location, Topography, and Drainage

Nowata County is located in the northeast part of Oklahoma bordering Kansas.

The topography of the county is shown on the Nowata and Vinita quadrangles of the U. S. G. S. topographic atlas scale 1:125,000 with 50 foot contours.

The Verdigris River flows in a north-south direction through the center of Nowata County. It drains all of the area of the county with the exception of the extreme western edge, where a number of creeks originate which flow into Caney River.

History of Oil Development

While Nowata County is now, in the days of the Seminole development, hardly ever mentioned as an oil producing area it was in the early development of the Oklahoma oil fields the most important territory. It was then known as the Cherokee shallow district. The Coody's Bluff-Alluwe pool is one of the largest almost solidly drilled oil fields in existence and almost continuous with it are the Delaware-Childers pool, the Delaware extension, and the Claggett pool. Quite a number of wells had a considerable initial production and most of them are producing yet.

The first oil wells in this district were drilled in sec. 32, T. 24 N., R. 17 E., in the Chelsea extension of the Coody's Bluff-Alluwe pool in Rogers County. It is said that an oil seep and showings in water wells led to the drilling. Real activity started in 1904, when it became possible to acquire valid leases[1]. Drilling soon extended into Nowata County where larger wells were encountered. In 1906 the maximum daily production in the Coody's Bluff-Alluwe-Chelsea pool was attained with more than 53,000 bbls. In 1907 the development extended into the Delaware-Childers pool but the main development there was in 1909 in which year 475 oil wells were completed and in 1910 with 673 new oil wells. The Delaware extension was in full activity in 1911. In the same year the gas on California Creek was discovered and the Adair oil pool in 1912.

New pools discovered since have been of less importance. Occasional drilling in the main pools is still going on but most of the wells are small. Practically all the drilling was done in periods of high prices for crude. While as late as 1911 wells with less than 10 bbls. initial production were plugged as uninteresting, in the last years properties where the initial production averages only a few barrels are drilled up with profit.

1. Shannon, C. W., Petroleum and natural gas in Oklahoma: Oklahoma Geol. Survey, Bull. 19, part 2, 1917.

For years most of the wells have been on vacuum, the casing head gasoline bringing a substantial income.

Very recently compressed air drive has been put in use on many leases, air intake wells are drilled and new wells showing for a fraction of a barrel natural are made to pay by this method. In the Elliott pool an increase in production of 240 per cent was obtained by repressuring the sand with gas and air[2].

While compressed air has shown very good results in Nowata County the author is of the opinion that underground mining[3] would still increase materially the ultimate recovery at a cost which is not prohibitive.

GEOLOGY

Stratigraphy

SURFACE FORMATIONS

The areal geology of Nowata County was first mapped by D. W. Ohern[4]. Unfortunately this map is so poorly printed, that the reader will get a better idea of the distribution of the surface formations by consulting the smaller scale map recently published by the United States Geological Survey[5]. A short description of the different formations shown on this map together with lists of characteristic fossils was published by the Oklahoma Survey[6].

The following formations, starting with the oldest, form the surface of Nowata County:

Pennsylvanian

CHEROKEE SHALE

Only the top of the Cherokee shale is exposed in the southeast part of the county and this formation shall be described under the heading subsurface formations.

FORT SCOTT LIMESTONE

The Fort Scott limestone consisting of two limestone ledges separated by black shale has a thickness of about 60 feet. Just below there are some coal and thin limestone ledges. Ohern has included these with the Fort Scott proper into his Claremore formation. This series is known by the drillers as the Oswego lime.

2. Lindsly, Ben E., The application of compressed air to the Elliott pool, Nowata county, Oklahoma: U. S. Bureau of Mines, Serial No. 2778, 1926.
3. Bloesch, Edward, Oil mining: Bull. Amer. Assoc. Pet. Geol., vol. 10, No. 4, 1926.
4. Ohern, D. W., The stratigraphy of the older Pennsylvanian rocks of northeastern Oklahoma: State Univ. of Okla., Research Bull. No. 4, 1910.
5. Miser, Hugh D., Geologic map of Oklahoma: 1:500,000, U. S. Geol. Survey, 1926.
6. Gould, Chas. N., and Decker, Charles E., Index to the stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35, 1925.

LABETTE SHALE

The Labette is a formation consisting principally of shale, but with a fairly prominent sandstone member in its upper part. The formation shows a decided increase in thickness from north to south. Near the Kansas line the thickness is only 100 feet (according to well logs), while in the southern end of Nowata County it is at least 200 feet.

PAWNEE LIMESTONE

The Pawnee, a massive fossiliferous limestone, varies in thickness from 25 to 50 feet in Nowata County. Ohern[7] gives the following section four miles northeast of Nowata:

Section of Pawnee Limestone, Nowata County.

	Feet
Limestone, massive, fine-grained	6
Shale, black, carbonaceous, fissile	5
Limestone, bluish, shaly in lower part	14
Shale, black (top of Labette)	
	25

BANDERA SHALE

The Bandera is a bluish to black carbonaceous clay shale varying in thickness from 20 feet or less to 50 feet (or even 70 feet according to well logs). It thins irregularly toward the south, and not far from the Nowata County line it pinches out entirely. The overlying and underlying limestones coalesce and are known as the Oologah limestone or "Big Lime" of the drillers.

ALTAMONT LIMESTONE

The Altamont is a cherty limestone 30 to 50 feet thick. It forms, together with the Pawnee limestone in the south part and with the Lenapah limestone in the north part, the high bluffs along the Verdigris River.

An interesting exposure is in the bed of the Verdigris River in sec. 21, T. 28 N., R. 16 E. There the top of the Altamont limestone is sandy and contains, besides cherty parts with marine fossils, some plant remains. Pieces of *Sigillaria* trunks several feet long can be seen with the bark changed to coal and the interior transformed into limestone. Smaller plant fragments are forming thin flakes of coal in the limestone, getting more numerous close to the coal-bearing shale lying on top of the limestone. To the writer's knowledge the presence of coal in limestone and also fossilized wood with a limestone matrix are unique.

7. Ohern, D. W., loc. cit. p. 21.

In this location the following section was measured:

Section on Verdigris River, Sec. 21, T. 28 N., R. 16 E.

Lenapah	Chert, loose, weathered Lenapah	
	Limestone, cherty	10
	Limestone, sandy and shaly	2
Nowata	Shale	75
	Shale, black, with coal	1
Altamont	Limestone	3

NOWATA SHALE

The interval between the Altamont and the next higher limestone consists of shale locally with lenticular sandstone. It has been called the Nowata shale. This shale interval increases from north to south. Its thickness is about 75 feet northeast of Lenapah, 130 feet near Nowata and 140 feet or more in the south part of the county.

LENAPAH LIMESTONE

The Lenapah is a dense blue, partly crystalline, fossiliferous limestone. Chert occurs mostly in the northern area. On Mormon Creek northwest of Nowata the writer observed two beds of crinoid breccia separated by clay and black shale, the latter having been observed in other places. At the type locality the Lenapah limestone is 20 feet thick. It decreases in thickness southward and measures 6 to 8 feet at Nowata. Then the outcrop swings westward around the headwaters of Double Creek, where exposures are poor. A good ledge of limestone caps the hill in sec. 14, T. 25 N., R. 15 E., and from there on only scattered exposures of crinoidal limestone are seen. Near the southwest corner of sec. 22, T. 25 N., R. 15 E., the limestone becomes conglomeratic and a ferrugineous breccia in the northeast corner of sec. 9, T. 24 N., R. 15 E., is the last observed exposure which the writer considers to be true Lenapah limestone.

The Lenapah limestone has generally been considered the equivalent of the Dawson coal. The writer thinks that this coal develops in the black shale mentioned above as being interstratified with the Lenapah limestone. No good exposures could be found of coal and limestone together. But in case there is but a single coal bed in the Dawson horizon, which is not absolutely certain, the Dawson coal with the adjacent black shales and local thin limestones is the exact equivalent of the Lenapah limestone.

COFFEYVILLE FORMATION

The Coffeyville formation has a thickness of 200 to 300 feet or even more, thickening from north to south. It consists principally of shale, also sandstone especially in the upper part, a limestone near the base in the south part of the county (Checkerboard limestone)

and also coal. The writer has observed a coal seam in sec. 16, T. 26 N., R. 14 E., of one foot thickness, which includes shale partings. A little lower in the section a three-inch lenticular coal bed is present. These coal beds are contained in the irregularly bedded sandstone near the top of the formation. The lower coal rests unconformably on the underlying sandstone.

HOGSHOOTER LIMESTONE

The Hogshooter is a massive, highly fossiliferous limestone of at least 10 feet thickness in the north part of the county but a little less in the south. It is the equivalent of the lower part of he Drum limestone of Kansas. In sec. 16, T. 28 N., R. 15 E., black carbonaceous shale was observed underlying the limestone, also on the M. K. & T. R. R. southwest of Coffeyville.

NELLIE BLY FORMATION

The shale-sandstone interval between the Hogshooter limestone and the Dewey limestone has been called the Nellie Bly formation. Its thickness near Wann is 50 feet[8] but increases considerably towards the southwest as 100 feet is the reported thickness at Ramona.

The top of the Drum limestone of Kansas becomes conglomeratic at the State line. Near Noxie, Okla., layers of conglomeratic limestone are interstratified with sandstone. The hill in the northwest part of sec. 28, T. 29 N., R. 15 E., is capped by limestone, conglomerate, and coarse sandstone. In the northwest part of sec. 3, T. 28 N., R. 15 E., the limestone finally grades into coarse sandstone, which is a part of the Nellie Bly formation.

DEWEY LIMESTONE

The highly fossiliferous Dewey limestone varies in thickness from 20 feet at the type locality at Dewey to 5 feet at a point in sec. 19, T. 28 N., R. 15 E., thinning northeastward. Close to this place the Dewey horizon is represented only by four inches of fossiliferous sandstone and some lime concretions, but true limestone can be traced as far north as the center of sec. 13, T. 28 N., R. 14 E. Here cross-bedded sandstone can be observed for one-half mile, indicating a regular delta. This may have raised the sea floor so that no limestone could be deposited. In some places, for instance in sections 10, 11, and 15, T. 27 N., R. 14 E., the limestone rests on fissile, black carbonaceous shale. Ohern[9] states correctly that the Dewey limestone is above the horizon of the Drum. Unfortunately the old erroneous idea was revived on the state map[10].

8. Ohern, D. W., loc. cit. p. 30.
9. Ohern, D. W., loc. cit. p. 31.
10. Miser, Hugh D., loc. cit.

OCHELATA FORMATION

The highest strata cropping out in Nowata County belong to the Ochelata formation, but only the lower 300 feet of it occur within the county. It consists of shale, considerable sandstone, and several limestone ledges, also traces of coal near the base (secs. 13 and 24, T. 28 N., R. 14 E.). In the upper part of this formation is the Stanton limestone[11] exposed only in the northwest corner of the county. Two more limestone horizons have been observed within the lower part of the Ochelata formation north of Wann. One or the other may possibly be the equivalent of the Avant limestone, but present field data are insufficient to establish these relations.

Pleistocene

Terrace gravels consisting of flint pebbles along the Verdigris River Valley and the alluvial silts shall only be mentioned.

SUBSURFACE FORMATIONS AND PRODUCING HORIZONS

Pennsylvanian

SHALLOW SANDS

The shallowest producing horizons in Nowata County occur in a pool in sec. 23, T. 29 N., R. 15 E., where small oil wells have been completed recently at an average depth of only 100 feet. According to the well logs there are two producing sands, one just above and one just below the Lenapah limestone. The latter is probably the Wayside sand of Kansas[12].

The sandstone occurring in the upper part of the Labette shale (Weiser sand of Kansas[13]) is reported in some well logs as having considerable thickness, as much as 80 feet in sec. 13 T. 27 N., R. 16 E., 65 feet in sec. 33, T. 26 N., R. 16 E., 60 feet in sec. 18, T. 26 N., R. 14 E., etc. Small gas production is reported from this sand in sec. 8, T. 28 N., R. 16 E., and in sec. 23, T. 28 N., R. 15 E. There are several wells in sec. 14, T. 28 N., R. 15 E., the largest of record being good for one-half million cu. ft. In sec. 2, T. 25 N., R. 14 E., a 12 barrel oil well was obtained in this horizon and a test in sec. 29, T. 28 N., R. 15 E., showed for two barrels.

The horizon of the Fort Scott limestone, called Oswego lime by the drillers, produces gas in a number of wells in different parts of the county. The largest wells on record had a capacity of 2¼ million cu. ft., and are located in sec. 36, T. 29 N., R. 14 E. The Oswego

11. This is the Piqua limestone of the Independence folio. Correlations with the Kansas section are none too certain, as the mapping of this folio is in part erroneous.
12. Williams, D. W., Correlation of producing sands in southeastern Kansas and northeastern Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 5, No. 2, 1921.
13. Williams, D. W., loc. cit.

gas does not always come from the same horizon. It is reported from the lime itself or from a break between the limestone ledges. Part of it really comes from the top of the Cherokee shale.

CHEROKEE SHALE

The Cherokee consists chiefly of shale of various kinds and includes several prominent sandstones and oil sands, thin limestones, and coal seams. The important coal near the top has already been mentioned with the Fort Scott limestone. As only the top of the Cherokee shale outcrops in Nowata County, its thickness had to be obtained from well logs only. These show a thickness of 500 feet at the State line, increasing toward the south to 600 or 700 feet in the south part of Nowata County, the maximum thickness being reported from sec. 23, T. 25 N., R. 16 E., and sec. 34, T. 25 N., R. 16 E. As the Cherokee shale was deposited on a rough erosional surface, the changes in thickness are irregular and variations of 100 feet occur in the same township.

There are three groups of producing sands in the Cherokee shale of Nowata County.

A sandstone series crops out between Chelsea and Catale. In this horizon several irregular sands of varying thickness are reported. These sands usually carry water. There is some scattered gas production, the only pool being located around the southeast corner of T. 29 N., R. 14 E. The largest well in sec. 31, T. 29 N., R. 15 E., is reported good for two million cu. ft. In sec. 3, T. 25 N., R. 17 E., a small oil pool was developed in this sand with initial productions of from two to five bbls. Oil from this horizon is reported from several places inside the Coody's Bluff-Alluwe pool. In sec. 11, T. 25 N., R. 14 E., a 10 barrel well was obtained.

BARTLESVILLE SAND

Most of the oil wells (all the large ones) in Nowata County produce from the Bartlesville sand, also some gas wells. This sand series, which crops out farther to the east, is known at the surface as the Bluejacket sandstone. Above the "main pay" there are often "stray sands" which produce in places and in others oil is reported from a "second pay." What is termed the "main pay" does not seem to be the same horizon all over the county. At the type locality near Bartlesville, the Bartlesville sand is usually reported as a single thick sand but toward the east in Nowata county this sand body splits up into different sand streaks. The upper, or stray sands, produce oil and gas in a few scattered localities. Most of the large production is from the main pay, but the following localities seem to produce mainly from the lower or second pay: The Adair pool in T. 26 N., R. 14 E. and T. 26 N., R. 15 E.; all the Bartlesville wells in T. 25 N., R. 14 E.; most of the wells in T. 25 N., R. 16 E.; secs. 31 and 32, T. 25 N., R. 17 E.; and the Chelsea extension in T. 24 N., R. 17 E.

The thickness of the Bartlesville sand varies considerably and in many places it thins out or turns into shale. Where producing, from 10 to 30 feet of sand are usually present and 50 feet seems to be about the maximum thickness. Wells drilled in recent years are usually small, but during the main development initial productions of several hundred barrels were numerous and in the Delaware-Childers pool a maximum initial production of 1,000 bbls. was attained. The Bartlesville gas wells are usually small. The largest on record is located in sec. 11, T. 26 N., R. 16 E., with a capacity of 1,800,000 cu. ft.

BURGESS SAND

At the base of the Cherokee or separated from the "Mississippi" lime by a thin body of shale many deep holes report a sand called Burgess. It is approximately at the horizon of the Hogshooter gas sand, which has been described as the fill of an old stream channel[14]. Not enough deep holes have been drilled in Nowata county to properly outline its distribution. As it is a basal sand deposited along the unconformity the Burgess sand is not of exactly the same age in different localities. This sand is usually thin, averaging only about 10 feet, but in sec. 16, T. 29 N., R. 16 E., 40 feet are reported, and in sec. 8, T. 25 N., R. 17 E., even 60 feet.

The Burgess sand has furnished several gas pools, the largest wells on record being two million cu. ft. in sec. 7, T. 25 N., R. 17 E., and 2½ million cu. ft. in sec. 35, T. 26 N., R. 17 E. The only Burgess oil production, which came to the writer's notice, is in the northwest part of T. 25 N., R. 17 E., the largest reported initial production being 35 bbls.

Mississippian

BOONE LIMESTONE

The Mississippian is represented largely by the Boone formation, a cherty limestone. The well logs sometimes report thin shale partings and sands, but this is, at least in part, sandy and shaly limestone. The green shale near the bottom is of Kinderhook age[15]. On account of an erosional unconformity on top the thickness of the Boone limestone varies considerably, according to available well records, from 210 feet in sec. 14, T. 26 N., R. 15 E., to 370 feet in sec. 22, T. 25 N.,

14. Berger, W. R., The extent and interpretation of the Hogshooter gas field: Bull. Amer. Assoc. Pet. Geol., vol. 3, 1919.
15. Snider, L. C., Geology of a portion of northeastern Oklahoma: Oklahoma Geol. Survey, Bull. 24, 1915.

R. 14 E. Porous streaks occur in the limestone carrying water or showings of oil or gas. No oil wells from this formation have come to the writer's attention in Nowata County, but there may be a few. Light gas production from the top of the Boone limestone occurs in the north part of the county, a well on record in sec. 14, T. 27 N., R. 16 E., having a capacity of one-half million cu. ft. In sec. 14, T. 26 N., R. 17 E., near Ruby, a well is said to have shown an initial volume of 15 million cu. ft., but this evidently did not hold up.

Recent discovery of Mayes deposits in Rogers County, Okla., and in Montgomery County, Kan.[16], indicate that some of the so-called Boone chert in Nowata County may be younger, but the writer was unable to locate well samples, which would decide this question.

CHATTANOOGA SHALE

The Chattanooga is a black carbonaceous shale formerly considered to be of Devonian age but now thought to belong to the Mississippian[17]. It is separated by an unconformity from the formations below, overlapping younger strata toward the south. Most deep logs in Nowata County report from 50 to 70 feet of Chattanooga shale with a minimum of 10 feet in sec. 25 T. 26 N., R. 14 E.

Siluro-Devonian

While upper Ordovician and Silurian sediments were probably deposited over the area, they are now missing. Most of the Devonian period was a time of erosion. The older sediments had been uplifted and were eroded in such a manner that the pre-Chattanooga sea floor consists of older formations the farther north one goes in Oklahoma[18]. At least several hundred feet of sediments were removed in the area covered by this report and this erosional unconformity is more pronounced than any other unconformity above or below with the exception of the granite floor.

Ordovician

ARBUCKLE LIMESTONE

Below the Chattanooga shale deep wells encounter a series of siliceous limestones, dolomitic in part. This series has been correlated with part of the Arbuckle limestone, the top having been eroded. It is of lower Ordovician age, possibly extending into the upper Cambrian. Only one test in Nowata County, located in sec. 27, T. 27 N., R. 16 E., went through it and showed a thickness of 775 feet.

16. Bush, F. A., Personal communication.
17. Ulrich, E. O., Fossiliferous boulders in the Ouachita "Caney" shale and the age of the shale containing them: Oklahoma Geo. Survey, Bull. 45, Fig. 2, 1927.
18. White, Luther H., Subsurface distribution and correlation of the pre-Chattanooga series of northeastern Oklahoma: Oklahoma Geol. Survey, Bull. 40-B, 1926.

There are several porous horizons in this series, which usually carry sulphur water but may produce oil or gas. One such horizon, the only one, which has actually produced oil is at or near the top of the formation. Only two places have produced oil in the Arbuckle limestone in Nowata County. One pool is located southeast of Coffeyville in Kansas and extends into secs. 15 and 16, T. 29 N., R. 16 E., in Oklahoma. The other pool is in secs. 16 and 21, T. 28 N., R. 16 E. The pay is usually penetrated only a few feet, as sulphur water soon appears. The largest reported initial production is in sec. 16, T. 28 N., R. 16 E., with 400 bbls.

Pre-Cambrian

GRANITE

The deepest hole drilled in Nowata County is located in sec. 27, T. 27 N., R. 16 E. It was drilled to 2,070 feet and reports lime to the bottom. The samples showed granite from 1,955 on down[19]. We may assume that in most places in Nowata County the Arbuckle limestone rests directly on granite or on reworked granite material.

NOTES ON PENNSYLVANIAN SEDIMENTATION

The Pennsylvanian, consisting mostly of shale with some sandstone and coal and an increasing amount of limestone from the Fort Scott on up, is essentially marine. No positive proof has been found of any fresh water or land deposits, but plant remains indicate the proximity of land in different periods. The various coals have been formed in coastal swamps, some beds of local extent probably in fresh water. Cross-bedding must have taken place in very shallow water and local unconformities may be due to temporary emergence or to submarine erosion. The sandstones are known to be lenticular partly pinching out, partly grading into shale. Shore lines were probably present, but the available logs can not be correlated with sufficient accuracy to work out such interesting and important details.

Several of the limestones also pinch out in this territory after becoming sandy and conglomeratic. This edge facies is usually characterized by crinoids and bryozoa.

Attention is called to deposits of black, carbonaceous shale connected with most limestone ledges and also with coal beds. To the writer's knowledge they have not been studied properly as to mode of deposition and contents of organic matter. A sample of such shale associated with the Hogshooter limestone collected behind the store at Hogshooter showed an oil content of two gallons to the ton[20]. These shales must be considered as possible source rocks for oil and gas.

19. Greene, F. C., Granite wells in the northern Mid-Continent region: Bull. Amer. Assoc. Pet. Geol., vol. 9, No. 2, 1925.
20. Dott, Robert H., Personal communication.

Structure

The normal dip of the surface beds is to the northwest at an average rate of 30 feet to the mile. On account of the southward increase in thickness of the section the strike of the lower beds is changed somewhat and local structural features are also modified with depth[21].

The normal dip is modified in numerous places by flattening, reverse dip, and by local changes in the strike, which form northwest plunging anticlines (noses). Very little detail work on the structure (surface or subsurface) of Nowata County has been done and none has been published. Reconnaissance work done by the writer indicates that anticlines (mostly domes) are fairly numerous, but that most of them are small. He has called attention to a small anticline east of Lenapah[22]. The U. S. Bureau of Mines has published a map of the Elliott pool contoured on the producing sand[23]. While such a sand surface only approximates structure[24], this map shows the presence of a northward plunging anticline.

On Plate I there is shown a cross-section north and south through R. 16 E. and two east-west cross-sections (through Nowata and Craig counties), one along the line between T. 28 N., and T. 29 N., the other one mile north of the south line of Nowata County. These cross-sections show the general attitude of the beds. The east-west sections show the west dip, while on the north-south section there is only a slight dip to the north. Some of the structural irregularities are also indicated, but only in a general way, as some logs had to be projected into the plane of the section. The sections also show the stratigraphy of the region, hard beds forming escarpments, lensing of sands, variation of thickness of certain beds, the erosional unconformity on top of the "Mississippi lime," and so on. (The Fayetteville-Pitkin series cropping out east of Vinita is included in the Cherokee, as it could not be identified in the well logs, and some cherty Mayes may be included in the Boone.

OIL AND GAS DEVELOPMENT

Accumulation

According to the anticlinal theory oil and gas accumulate on anticlines. This is only true where the sand is continuous, regular, and fully saturated. Where the sand is lenticular the accumulation takes

21. Bloesch, Edward, Unconformities in Oklahoma and their importance in petroleum geology: Bull. Amer. Assoc. Pet. Geol., vol. 3, 1919.
Leversen, A. I., Convergence studies in the Mid-Continent region: Bull. Amer. Assoc. Pet. Geol., vol. 11, No. 7, 1927.
22. Bloesch, Edward. Value of oil geology in the Mid-Continent field: Bull. Amer. Assoc. Pet. Geol. vol. 2, p. 129, 1918.
23. Lindsly, Ben E., loc. cit. Fig. 1.
24. Bloesch, Edward. Remarks on subsurface contouring: Bull. Amer. Assoc. Pet. Geol., vol. 6, No. 4, 1922.

place in the upper part of the sand lenses instead of the anticlines. Thickness and porosity may decrease sufficiently to act as a barrier without actual pinching out of the sand. Porous sands which carry lots of water in the lower places can only be expected to produce on closure (due entirely to structure or in part to lensing). Highly water bearing horizons in Nowata County are the sand in the Labette shale and the top of the Arbuckle limestone. Where sands are not fully saturated the high places contain gas only under pressure below normal and the oil is located down the dip. This condition is well known in some of the Appalachian fields and also occurs in eastern Kansas. In Nowata County there are indications of it, but some of the gas pools show normal pressure. Sometimes sand lenses are very large forming a blanket over a large area but terminating rather abruptly. Such sands[25] may furnish extended oil pools with an irregular boundary, structural conditions only limiting the pool on the lower side where the water level follows structural contours. The Bartlesville sand group is famous for such pools (Glenn Pool, Burbank) and most of the Bartlesville oil pools in Nowata County are thought to be of such a nature.

MAIN POOLS OF NOWATA COUNTY

A map covering most of Nowata County and showing all the wells is contained in Bull. 19 of the Oklahoma Survey[26]. While quite a number of wells have been drilled since, it still gives a good general idea of the production. A map showing the development in the whole area has recently been published by the U. S. Geological Survey[27].

COODY'S BLUFF-ALLUWE POOL[28]

Including the so called Chelsea extension in Rogers County the Coody's Bluff-Alluwe pool covers an area of 70 square miles, the main production being from the Bartlesville sand group. An upper and a lower sand are present, but can not be discerned readily from the available well logs. The upper sand seems to furnish the production in the north end of the pool, while the lower is productive in the south end. In a few places there is oil production from shallower sands and the Burgess sand is producing oil and gas in places. In 1921 a check showed about 8,300 producing wells in this pool and most of them are producing yet.

The development started near Chelsea, the first real drilling campaign getting under way in 1904, but soon extended north on account

25. Powers, Sidney, Petroleum geology in Oklahoma: Oklahoma Geol. Survey, Bull. 40-G, p. 12, 1926, calls them sheet sands.
26. Shannon, C. W., loc. cit. plate 29.
27. Pusey, Lewis B., Oil and gas fields of the state of Oklahoma: 1:500,000, U. S. Geol. Survey, 1927.
28. One continuous pool and not separated as shown on map of oil and gas producing areas in Oklahoma by Bess Mills-Bullard, Oklahoma Geol. Survey 1926.

of larger wells. The wells near Coody's Bluff had initial productions of as much as 500 bbls., but also north of Alluwe initial productions of 200 and 300 bbls. were occasionally developed. The size of the wells depends on thickness and porosity of the sand, the porosity being of prime importance. Late drilling usually resulted in small wells, but an occasional big one inside of the pool indicates important changes in sand conditions and lenticularity, if not of the sand, at least of the porous streaks. In 1921 the average production per well in the south part of the pool between Alluwe and Chelsea was estimated at one-half barrel, the wells in the north part being somewhat larger. Since then repressuring with gas or air has been introduced on many properties with good results, but no actual production figures are available.

The Coody's Bluff-Alluwe pool is a typical large sandlens pool. The reported big anticline[29] does not exist. The few logs of dry holes available on the east edge of the pool do not show water and the Bartlesville sand is thin or missing. Folding may have helped the accumulation in the Chelsea extension where flattening of the strata and even local east dip were observed. Inside of the pool east dip was seen in a few places, which may account for some of the shallow and also possibly the Burgess sand production. The west boundary of the pool is at least in part due to the water table, in other words it follows structural lines. In several places dips steeper than normal were seen along the west edge of the pool. While the accumulation is essentially due to sand conditions, structure also plays a minor part in the outline of the pool.

There are a few unimportant pools east of the Coody's Bluff-Alluwe pool, one of which, containing Burgess sand wells, is differentiated as the Salt Creek pool on the map of the U. S. Geological Survey.

DELAWARE-CHILDERS POOL

North of the Coody's Bluff-Alluwe pool and practically continuous with it is the Delaware-Childers pool. From the town of Delaware it extends east for nearly 7 miles and the Delaware extension, which is continuous with it, extends west-northwest for another 7 miles. Thus the pool has a length of 14 miles and a width varying from one-fourth mile to two miles. As far as could be learned all the production is from the Bartlesville sand and the pool is a typical sandlens pool, structure only affecting the water level on the west end. The Delaware extension even resembles the shoe string pools of Kansas. The wells in the extreme east end start near the top of the Labette shale and the ones in the extreme west end near the Dewey limestone. Thus it can be seen that the depth of the wells in the pool varies considerably from east to west.

29. Shannon, C. W., loc. cit. p. 349.

The first production in the Delaware-Childers pool was obtained in 1907 and most of the drilling was done from 1908 to 1910, while the Delaware extension was mainly developed in 1910 and 1911. Many wells had an initial production of several hundred barrels and in the Delaware-Childers pool a few wells up to 1,000 bbls. are said to have been obtained.

NOWATA OR CLAGGETT POOL

The Nowata or Claggett pool is located near the town of Nowata and almost joins the Coody's Bluff-Alluwe pool in the east and the Delaware pool in the north. It covers several square miles, but as most of the wells, which also produce from the Bartlesville sand, were small, development has not been as solid as in the pools already mentioned.

HOGSHOOTER GAS POOL

The Hogshooter gas pool at one time the most important one in Oklahoma, which furnished gas to Kansas City, is located mostly in Washington County but extends across the line into Nowata County. The producing sand lies on top of the "Mississippi" lime about at the horizon of the Burgess sand of Nowata County and represents the fill of an old stream channel[30].

ADAIR POOL

The Adair pool is located in and around the southeast part of T. 26 N., R. 14 E. It has several extensions, some of which have been termed Oglesby and Glen Oak pool. It was opened in 1912. The production is from the Bartlesville sand. Indications of anticlinal structure were noticed but no details worked out.

WANN

Near Wann on both sides of the county line there are a number of small pools producing oil from the Bartlesville sand and also some shallow gas.

CALIFORNIA CREEK OR ELLIOTT POOL

A pool extending nearly continuously from sec. 10, T. 27 N., R. 15 E., to sec. 11, T. 28 N., R. 15 E., is known as California Creek pool. It produces mostly gas but about 540 acres situated mostly in sec. 3, T. 27 N., R. 15 E., are oil producing. This oil pool has been described under the name of Elliott pool[31]. The oil and most of the gas are from the Bartlesville sand, but the Burgess sand, the sand in the Labette shale, and a 220-foot sand[32] are also producing. This

30. Berger, W. R., loc. cit.
31. Lindsly, Ben E., loc. cit.
32. Shannon, C. W., loc. cit. p. 348.

long, narrow pool is anticlinal and the accumulation is at least in part due to structure, but outside of the oil producing area the structure has not been worked out. The first well was drilled in 1909. Most of the oil area was developed in 1910 and in the spring of 1911, with an initial production of about 250 bbls. to the well and a maximum of 700 bbls. The Bartlesville sand is 900 to 1,000 feet deep.

SOUTH COFFEYVILLE

Drilling around South Coffeyville, mostly started in search of gas for use in Coffeyville, has opened several small pools.

In secs. 23 and 26, T. 29 N., R. 15 E., oil and gas were developed in 1915 and 1916 in the Bartlesville sand and recently small oil wells were drilled, which produce near the Lenapah limestone as stated above. Their depth is only 100 feet.

A number of gas wells producing from the Bartlesville sand (at least a few on which information is available) are located in secs. 16, 22, 27, and 34, T. 29 N., R. 15 E.

Along the State line east of Coffeyville an oil pool in the top of the Arbuckle limestone was developed in 1924 in an area which had already produced shallow gas. Only a few wells are located in Oklahoma in secs. 15 and 16, T. 29 N., R. 16 E. The pay is encountered between 1,200 and 1,300 feet at or near the top of the Arbuckle limestone. The producing stratum is thin and sulphur water is encountered immediately below. The largest well in this pool on the Oklahoma side had an initial production of 165 bbls. Surface and subsurface data show that this pool is located on a dome with at least 40 feet of closure.

Another Arbuckle lime pool opened shortly afterwards is located in secs. 16 and 21, T. 28 N., R. 16 E. The pay is at the same depth and an initial production of 400 bbls. is on record. There is also some gas production from the Oswego and from the Bartlesville sand in this pool. It is located on the same line of folding on a pronounced dome.

WEIMER GAS POOL

About 10 gas wells were drilled on a well defined dome, most of them located in sec. 1, T. 27 N., R. 17 E. The majority of these wells is still producing.

FUTURE POSSIBILITIES

Since 1912 new development in Nowata County resulted only in small pools and the new wells were, with notable exceptions, small. Most of the drilling took place in periods of a high oil market, while in times of low prices it was practically at a standstill. The same

will take place in the future. While the county has been drilled up to such an extent that new important pools can hardly be expected, small new pools and new wells in the old fields can be looked for and the principal chances shall be pointed out.

New gas production can be expected in different parts of the county from the Oswego down to the top of the "Mississippi" lime, but these gas wells are likely to be small. Most of this gas will be found on anticlines, especially on domes, which in most places can be worked out from surface exposures, but some in the upper part of porous lenses, especially in the Bartlesville sand.

Oil in the usual water bearing horizons will also mostly be found on anticlines, while production from lenticular sands is much harder to predict and can only be figured out from well logs.

Production in shallow sands can not only be expected in undrilled territory, but it seems likely that in developing the main pools small wells in the upper sands have been passed up. New Bartlesville sand wells inside or along the edges of the old main pools can be drilled in a number of places, but with some exceptions they are going to be very small. Some Bartlesville sand wells stopped in the upper pay where production in the lower pay may be possible and also some more Burgess sand production is likely to be found within the old Bartlesville sand pools.

Only a few tests in Nowata County have been drilled to the Arbuckle limestone and, as favorable structure is known to exist, there are chances for additional pools in this horizon. It may be said, that the top of the Arbuckle limestone is so porous (or possibly cavernous) and the water comes in so quick, that on a smaller dome one well located exactly on the apex would be sufficient to drain the pool. On the other hand the topmost part of the dome often shifts slightly from the surface to the depth of the Arbuckle pay on account of several pronounced unconformities and it takes several wells to locate the highest point. Therefore drilling to the Arbuckle horizon can only be recommended on fair sized domes. There are several porous horizons in the middle of the Arbuckle limestone to 500 or 600 feet below the top. In the only deep test in Nowata County no showings of oil or gas are reported from these horizons but the writer considers production not impossible as most limestones contain, when deposited, enough organic material to form oil or gas. This oil or gas could accumulate in the porous streaks, providing the location is on closed anticlinal structure.

The main future of the oil industry in Nowata County lies in increased recovery by new production methods such as repressuring and underground mining.

CRAIG COUNTY

Location, Topography and Drainage

Craig County is located in the northeast part of the State bordering Kansas and adjoining Nowata County on the east.

The topography of the county is shown on the Vinita quadrangle of the U. S. Geological Survey topographic atlas, scale 1: 125,000, (the extreme east portion on the Wyandotte quadrangle) with 50 foot contours.

While the Neosho River forms the boundary in the northeast corner of the county practically all of the county is drained by Cabin Creek, which empties into the Neosho River after leaving the county on its south line. A small area in the northwest part of the county lies in the drainage basin of the Verdigris River.

GEOLOGY

Stratigraphy

SURFACE FORMATIONS

The formations cropping out in Craig County are shown on the State map[33]

Mississippian

CHATTANOOGA SHALE

The Chattanooga shale, probably of Mississippian age but formerly considered Devonian, is a black, carbonaceous shale cropping out in a small area on Cabin Creek near the south line of the county. In well logs its thickness varies from 10 to 50 feet.

BOONE LIMESTONE

Unconformably above the Chattanooga shale is the Boone, a cherty limestone with a thickness of from 300 to about 400 feet. Some of the well logs show the green shale interstratified with the basal beds, denoting Kinderhook age. Near the surface the lime is leached out and only porous chert is left. While the upper part is all cherty, in the lower part layers of flint, which have been used as raw material for weapons by the Indians, alternate with more pure limestone, and Crinoid breccia has been observed.

MAYES FORMATION

The Boone surface is an erosional unconformity and the overlying formations have been deposited in depressions of this surface. The Mayes formation of lower Chester and upper Meramecian age

33. Miser, Hugh D., loc. cit.

consists mostly of limestone with some shale. It is poorly exposed, probably present only in a part of the area, either on account of nondeposition or later erosion, and has a reported maximum thickness of 50 feet[34]. Snider[35] has collected fossils from this formation in Little Cabin Creek east of Vinita.

FAYETTEVILLE SHALE

The Fayetteville consists mainly of dark shale, but limestone is also present. Exposures east and south of Vinita indicate a maximum thickness of at least 60 feet[36]. This formation also seems to be missing in places.

PITKIN LIMESTONE

The Pitkin limestone, according to Snider[37] has not been observed north of T. 18 N., due to erosion. According to Buchanan[38] at least some patches of this formation have been preserved.

Recent investigations, not yet finished, indicate that the stratigraphy of the Mississippian of Craig County should be revised.

Pennsylvanian

CHEROKEE SHALE

The Cherokee shale rests unconformably on the Mississippian. Logs show a thickness of 500 feet in the northeast part (T. 28 N., R. 20 E., and T. 29 N., R. 19 E.) to 640 feet in the southwest part of the county (T. 26 N., R. 18 E.).

This formation consists largely of shale with sandstone, coal seams, and a few thin limestones. Near the middle is the Bluejacket sandstone, equivalent to the Bartlesville sand, a series of sandstones and sandy shales of variable character and of an aggregate thickness of 50 or 60 feet. It forms a prominent escarpment, as does another sandstone in the upper part of the formation. Close to the "Mississippi" lime there is also an oil sand, called the Burgess sand, which probably belongs to the Cherokee. Coal occurs at the base of the Bluejacket sandstone, the Cherokee coal above the Bluejacket, and the Fort Scott coal (several beds) at the top of the formation. Thin limestones near the top forms a transition to the Fort Scott limestone (Claremore formation of Ohern). Gas is known to occur close to the top of the Cherokee shale.

FORT SCOTT LIMESTONE

The Fort Scott limestone consists of a lower limestone member 5 to 18 feet thick, a middle member of black shale 7 to 10 feet thick,

34. Shannon, C. W., loc. cit. p. 149.
35. Snider, L. C., loc. cit. p. 30.
36. Snider, L. C., loc. cit. p. 37.
37. Snider, L. C., loc. cit. p. 41.
38. Buchanan, George S., The distribution and correlation of the Mississippian of Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 11, No. 12, Fig. 6, 1927.

and an upper limestone 4 to 10 feet thick (in well logs reported as much as 40 feet). Gas is known to occur at or near this horizon (Oswego lime gas).

LABETTE SHALE

The Labette is a shale formation which contains thin sandstone especially near the top. It occurs, like the higher beds, only in the northwest part of the county. A thickness of 100 to 120 feet is reported in Craig County[39], but a log in sec. 21, T. 29 N., R. 18 E., shows only 70 feet.

PAWNEE LIMESTONE

The Pawnee is a massive, somewhat cherty limestone of about 30 feet thickness.

BANDERA SHALE

The Bandera shale, which is arenaceous in places, has a thickness of about 100 feet at the Kansas line, thinning to the south.

ALTAMONT LIMESTONE

The Altamont limestone, the highest Pennsylvanian formation cropping out in Craig County has a thickness of about 30 feet.

Pleistocene

Flint gravels occur in Craig County, but they do not seem to be prominent and have not been studied.

Recent

An alluvial valley is developed along Neosho River and some valley fill is present along all the creeks.

Prominent talus deposits can be seen along bluffs of Boone chert, which are recent in part but in part probably older.

SUBSURFACE FORMATIONS

The following formations do not crop out in Craig County but are encountered in deep drilling:

ORDOVICIAN

ARBUCKLE LIMESTONE

Unconformably below the Chattanooga shale occurs a thick series of siliceous limestone and dolomite correlated with the Arbuckle lime-

39. Gould, Chas. N., and Decker, Charles E., loc. cit. p. 66.

stone of south-central Oklahoma. The top of this formation is a producing horizon. Only four well logs are available from Craig County, which go through this formation. They show the following thicknesses: 1,060 feet in sec. 34, T. 29 N., R. 19 E.; 1,208 feet in sec. 29, T. 25 N., R. 20 E.; 1,284 feet in sec. 32, T. 25 N., R. 21 E.; and 640 feet in sec. 29, T. 28 N., R. 21 E. The lower part of this formation may be of Cambrian age.

CAMBRIAN

REAGAN (?) SANDSTONE

In three of the deep wells a sand is reported below the Arbuckle series; 97 feet in sec. 29, T. 25 N., R. 20 E.; 14 feet in sec. 32, T. 25 N., R. 21 E., and 50 feet with about 30 feet of sand and shale below in sec. 29, T. 28 N. R. 21 E. While these sands may be part of the Arbuckle series just as higher, more siliceous parts are reported as sands, they may be basal sands or may possibly represent an equivalent of the Reagan sandstone of the Arbuckle region or the Lamotte sandstone of Missouri.

PRE-CAMBRIAN

GRANITE

The three last mentioned wells went into granite below the Reagan (?), while the one in sec. 34, T. 29 N., R. 19 E., reached the granite at the base of the Arbuckle limestone. The well in sec. 29, T. 25 N., R. 20 E., penetrated the granite for 491 feet.

Another granite well is reported from sec. 24, T. 24 N., R. 19 E.,[40], but could not be found. The granite well mentioned in sec. 19, T. 25 N., R. 20 E., also could not be located and has probably been mixed up with the one in sec. 29, T. 25 N., R. 20 E.

Structure

The average dip of the surface strata in Craig County is to the northwest at a rate of about 30 feet to the mile.

Variations from this dip seem to be numerous, as flattening and reverse dips can be observed in many places. These reversals form anticlines which are usually short and dome-shaped. The writer has mapped an area in the north part of the county which shows the character of these low folds and is given on Figure 2. Most of the points are on top of the upper Fort Scott limestone. Erosion has removed the overlying Labette shale and it is noteworthy how closely drainage follows the structural details. Other similar domes are reported from the north and west part of the county.

40. Greene, F. C., loc. cit. p. 352.

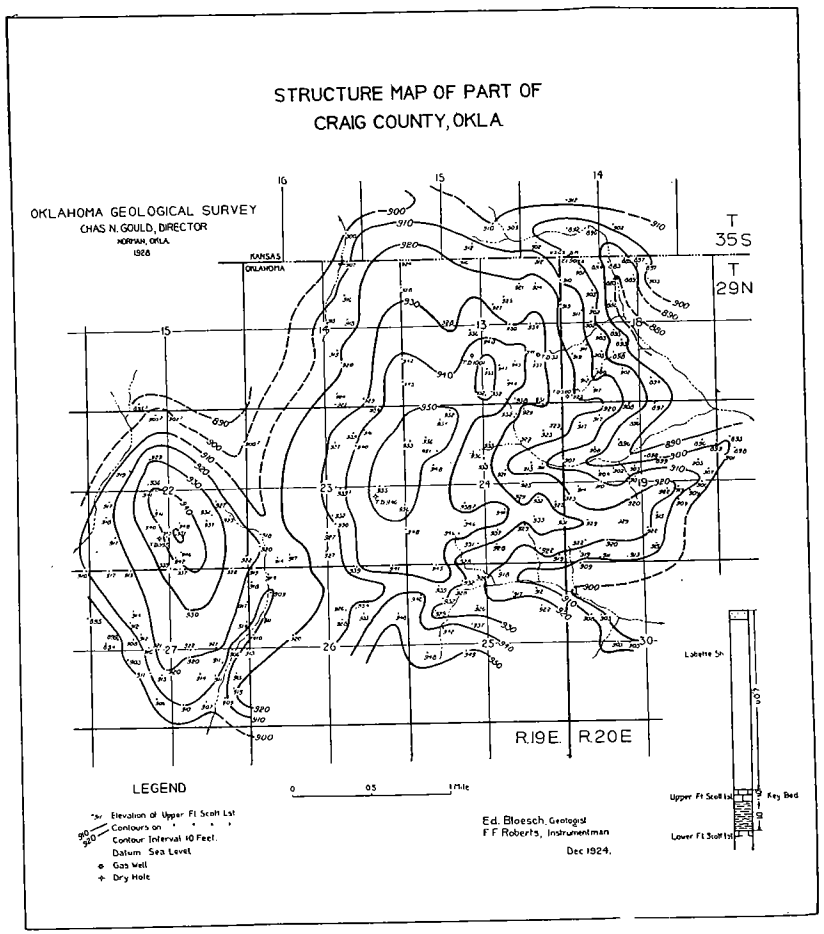

Figure 2.

More pronounced structural conditions exist in the extreme southeast part of Craig County. There dips of over 5 degrees have been observed by the writer. The main structural feature is the Horse Creek anticline, which extends from the northwest part of Delaware County in a southwesterly direction into Craig County and is plainly visible on Cabin Creek. It has been described by Siebenthal[41]

41. Siebenthal, C. E., Mineral resources of northeastern Oklahoma: U. S. Geol. Survey, Bull. 340, p. 198, 1908.

OIL AND GAS DEVELOPMENT

Main Areas of Development

Quite a number of tests for oil or gas have been drilled in Craig County, but the results have been mostly disappointing.

A number of small scattered gas wells were obtained and three small oil pools, one of which straddles the Rogers County line.

Near Catale in Rogers County there are several small oil pools and one of these, extending into Craig County, is known in the literature as Vinita pool. The wells near Catale are producing oil and gas from the Burgess sand and also oil from the Arbuckle limestone, but the wells are small. No information is available on the few wells on the Craig County side in the northwest part of T. 24 N., R. 19 E.

A dozen oil wells were drilled near Booker school. The ones in sec. 28, T. 25 N., R. 18 E., are still producing. Judging from the log of a now abandoned oil well in sec. 32, T. 25 N., R. 18 E., this production is probably from the Burgess sand.

In sec. 20, T. 26 N., R. 18 E., an oil pool was opened in 1916 with several small wells in the Bartlesville and in the Burgess sand. These wells were never operated steadily.

In Bulletin 19 of the Oklahoma survey an oil pool producing from the Burgess sand is mentioned in T. 28 N., R. 18 E., under the name of Weimer pool[42]. No oil wells are known in that area the only production being the Weimer gas pool across the line in Nowata County.

In sec. 21, T. 29 N., R. 18 E., a well reported good for 50 bbls. was completed in the Arbuckle limestone, but a second one proved dry and the first one has never produced for lack of pipeline facilities.

Future Possibilities

Judging from past performances no important oil or gas production can be expected from Craig County. Still there are numerous places in the county which could be drilled with the chance of getting small wells, but they are only of interest in times of big demand.

As to general chances the county can be divided into the northwest and the southeast part.

In the southeast part chances for production are practically confined to the Arbuckle limestone of which very little is known, with a possibility in the sand at the base [Reagan (?) sandstone].

In the northwest part there are also possibilities for production in the Pennsylvanian. In most any part of this area, where local

42. Shannon, C. W., loc. cit. p. 150.

structural and sand conditions are favorable, it should be possible to obtain gas at least for local consumption. Oil possibilities are indicated by previous drilling as mentioned above. Pennsylvanian production especially from the Bartlesville sand can be expected to be limited to areas with exceptionally favorable sand conditions, while Arbuckle production occurs only on well defined domes.

Unless favorable sand conditions are already proved by previous drilling new tests ought to be located on the most favorable anticlines, as this would give a chance for production from several horizons. On the other hand pronounced doming alone is no guarantee for paying production. This may plainly be seen from Figure 2, where several domes were mapped. The only production is from a well only 35 feet deep drilled for water and which encountered gas just below the Fort Scott limestone. This well has been supplying a farm house with gas for 20 years. The Bartlesville sand in this area contains gas, but only in small quantities. The Burgess sand is missing. Three tests, well located as to structure, were drilled to the Arbuckle limestone, one with a slight showing of oil. All three encountered water. Additional drilling for this horizon in Craig County should only be done on higher domes than these or in localities closer to actual Arbuckle production.