OKLAHOMA GEOLOGICAL SURVEY
Chas. N. Gould, Director

Bulletin No. 40-K

OIL AND GAS IN OKLAHOMA

GEOLOGY OF GARVIN COUNTY

By
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THE ROBBERSON FIELD

By
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NORMAN
MAY, 1927

GARVIN COUNTY

By

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ACKNOWLEDGMENTS

Many of the details in Part I were worked out while the writer was in the employ of the Carter Oil Co. This opportunity is taken to thank L. Murray Neumann, chief geologist of the Carter Oil Company, and A. L. Beekly, chief geologist of the Mid-Continent Petroleum Corporation, for their kindness in permitting this publication.

The writer wishes also to thank E. C. Case, of the University of Michigan, Sidney Powers, Frank C. Greene, A. L. Beekly, George S. Buchanan and H. W. Peabody for valuable suggestions and criticisms.

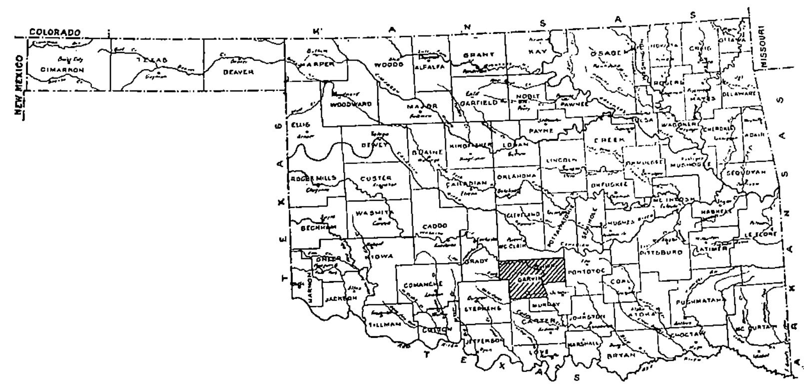


Figure 18—Index map of Oklahoma showing location of Garvin County.

STRATIGRAPHY

BEDS EXPOSED AT THE SURFACE

Red beds, generally regarded as of upper Pennsylvanian and Permian (Permo-Carboniferous of Case) age crop out in Garvin County. Case[1] uses the term "Permo-Carboniferous conditions" as practically synonymous with "red bed conditions" and shows that such conditions were first initiated in eastern North America well

1. Case, E. C., Permo-Carboniferous conditions versus Permo-Carboniferous time: Jour. of Geol., vol. XXVI, No. 6, pp. 500-506, 1918.

(This report originally issued as Bulletin 40-K, May, 1927).

down in the Pennsylvanian[2]. The upper Pennsylvanian of Garvin County was deposited largely under red bed conditions, and passes with no apparent break into the overlying Permian (Permo-Carboniferous).

These red beds have been designated Pontotoc terrane and Enid or Clear Fork-Wichita group, respectively. They are overlain by Cretaceous (?) shales and sandstone, by Tertiary gravels and river sands, and by recent alluvium. The areal distribution of the various formations is shown on the accompanying areal geologic map. Map No. XVII.

PALEOZOIC FORMATIONS

PONTOTOC TERRANE

This name was given by George Morgan[3] to a series of red beds, arkosic sandstones, limestone conglomerates and limestones which crop out in western Pontotoc, eastern Garvin and northern Murray counties. He subdivided the terrane into three units which he designated Vanoss formation, Stratford formation and Konawa formation. The principal lithologic characteristic of the rocks of this terrane is the presence of arkosic material, which is virtually absent from the overlying and underlying formations.

VANOSS FORMATION

Only the uppermost part of this formation is exposed in Garvin County. It is found in the southeastern part of T. 3 N., R. 3 E. and in the eastern and central part of T. 2 N., R. 3 E.

Near the top of the Vanoss formation occurs a 10 to 20 foot, persistent bed of gray, coarse-grained, arkosic sandstone, which can be traced with considerable certainty from the vicinity of Vanoss to and across T. 2 N., R. 3 E. This and a small thickness of underlying shales and sandstones comprise all of the formation exposed in Garvin County.

STRATFORD FORMATION

According to Morgan[4] "the base of the Stratford formation is a series of limestones which constitute the Hart limestone member." From a rather detailed study of the area, the writer is inclined to the opinion that the base of the limestone series does not occur at the same stratigraphic position in all outcrops, but that from Hart northward this base seems to progress upward across the bedding plane.

At Hart the arkosic sandstone which lies at the top of the Vanoss formation is succeeded directly by limestone. In the escarpment

2. Case, E. C., Environment of vertebrate life in Paleozoic in North America: Carnegie Inst., Washington, Pub. 283, 1919.
3. Morgan, George D., Geology of the Stonewall quadrangle: Bu. of Geol., Bull. 2, p. 132, 1924.
4. Op. cit., p. 137.

one and one-half miles west of Vanoss[5] the following section was measured:

Section 1½ miles West of Vanoss.

	Feet
Hard, white limestone, rich in arkosic materials.	
Buff, cellular limestone, probably of septarian origin	2
Arkosic sandstone	2
Red shales with gray sandstone streaks	25
Arkosic sandstone (considered by the writer to be the same bed as found at Hart).	

The cellular limestone listed above occurs over several sections in the western part of T. 3 N., R. 4 E., and makes a very satisfactory marker. Other buff, cellular beds occur in the stratigraphic column further south, but this particular bed is quite persistent and the interval between it and the arkosic sandstone at the top of the Vanoss formation is fairly constant.

In section 29, T. 4 N., R. 4 E., according to the writer's interpretation of local structure and stratigraphy, the lowermost bed of limestone is some 150 feet higher, stratigraphically, than the base of the limestones at Hart. The underlying material is red shale with some limestone concretions and occasional arkosic sandstone beds.

Morgan describes an inlier of Hart limestone[6], surrounded by Guertie sand, in the bed of a creek in the eastern part of sec. 2, T. 4 N., R. 3 E., which the writer correlates with the bed occurring in sec. 29, T. 4 N., R. 4 E. Loomis[7] in 1922 described this occurrence as a Pennsylvanian limestone surrounded by Permian red beds. No Hart limestone can be found north of this point.

The Hart limestone proper is a grayish-white, chalky to hard, in part chemically precipitated limestone, interbedded with and grading laterally into red shales and gray arkosic sandstones (Plate V, A, B, C). The lower foot or so of limestone ledges, where they lie in contact with shale, locally shows a cellular structure (Plate V, D), and single beds of this cellular material occur in the shale in many places. This material probably owes its origin to vein-filling in the shale by deposition from percolating calcareous waters.

The shales are all highly calcareous, and often contain beds of limestone nodules. Calcium carbonate seems to be the principal cementing material in the sandstones.

The Stratford formation might be roughly divided into two units on the basis of the greater percentage of limestones in the lower part. The contact lies some two miles west of Stratford. The upper part of the formation consists of a series of predominately red

5. Morgan, Geo. D., Op. cit., p. 138, Plate XX.
6. Op. cit., p. 139.
7. Loomis, Harve, Geologic Note: Bull. Amer. Assoc. Pet. Geol., vol. 6, p. 54, 1922.

shales with a few beds of gray to brown arkosic sandstones, limestone nodules and beds of limestone. Individual beds are locally quite thick and laterally persistent.

The Stratford formation covers the eastern third of Garvin County, and also crops out in a small exposure south of Wildhorse Creek, in T. 1 N., Rs. 1 E. and 1 W. The total thickness of the formation is approximately 450 feet.

KONAWA FORMATION

Morgan[3] applied this name to a series of red shales and sandstones cropping out just north of the Garvin County line, in McClain, northwest Pontotoc and southern Pottawatomie counties, which he regarded as younger than, and overlapping upon the Stratford formation, though he could never find the two in contact.

Such an interpretation has some merit, because of the lithologic difference between the Stratford and Konawa formations, and the similarity between the Konawa and the overlying Enid beds. It is not impossible that the Konawa formation represents the basal Enid of this region, older than the Enid group of Garvin County. The writer, however, is inclined to look upon the Konawa formation as merely a lateral phase of the Stratford formation, due to depositional factors. This will be discussed more at length under "deposition."

ENID GROUP

The series of red shales and sandstones, approximately 1,100 feet thick, which lie between the top of the Pontotoc terrane and the base of the Duncan sandstone is now generally regarded as equivalent to most of the Enid group of northern Oklahoma, and to the Clear Fork-Wichita group of Texas.

The writer was able to subdivide this group into eight fairly distinct lithologic units, based on the predominance of sandstone in some of shale in others. (See Fig. 19). Though in places obscure and difficult to recognize, these subdivisions seem sufficiently definite to make practicable their isolation and mapping. The areal extent of these units was checked by detailed structure mapping with a plane table. Some of the sandstone units cap escarpments which can be readily followed considerable distances. As this is the first

Explanation of Plate V

A. Massive Hart limestone along east line of sec. 7, T. 3 N., R. 4 E.
B. Looking north from the slope of hill in C. The same series of beds is exposed, with limestone making the bulk of the thickness.
C. Shales and limestone rubble of middle part of Hart limestone in high hill in the south half of sec. 18 T. 3 N., R. 4 E.
D. Buff, cellular bed of limestone which is a good marker in the western part of T. 3 N., R. 4 E. Other similar beds occur and all are usually found at the base of a limestone series where in contact with shale.

3. Op. cit., p. 140.

PLATE V.

THE HART LIMESTONE MEMBER OF THE STRATFORD FORMATION, IN WESTERN PONTOTOC COUNTY.

attempt to subdivide this series, these units are provisional only, and will be designated by numbers rather than by geographic names.

The sandstones vary from rather hard, thin, gray and black ledges to massive, soft, red, yellow and brown series, with occasional thin, white beds. The sand grains are small and of uniform size. Arkosic material is entirely absent, except perhaps, for a very slight amount in the base of the group. The sandstones are all more or less cross-bedded. They are quite similar in general appearance, and were it not for the shale intervals, could be distinguished only with great difficulty, except that the sandstones of Unit 1 are not red, while those in Unit 3 and above, are, in most places, distinctly red. The presence of the intervening shale units, however, permits of very satisfactory subdivision.

The shales are for the most part maroon, and are rather calcareous, with many zones of limestone rubble and calcareous nodules, locally with cellular structure. There are no distinct beds of limestone such as appear in the Stratford formation. Beds of barite rosette concre'ions occur at some horizons. (Fig. 19).

Unit 1

The Enid group in Garvin County begins with a group of beds consisting of two massive sandstones separated by a shale interval. This group is well developed in the vicinity of Civit, Pauls Valley and Wynnewood. A generalized section is as follows:

Generalized Section of Unit 1, Enid Group, in Garvin County.

	Feet
(Upper)—Sandstone, massive to thin-bedded, mineral-stained yellow to black	35
(Middle)—Shales, red with thin brown and white streaks of sandstones	65
(Lower)—Sandstone, massive, brown and black	40
	140

On the whole, the sandstones of the lower part of Unit 1 are massive, of medium hardness, black and brown in color. The middle member is mainly red shale, with a few dark sandstone ledges and one or two bands of white sand, a foot or two thick. In the western part of T. 4 N., R. 2 E. the latter make very good markers for determining local structure. The sandstones of the upper member are harder, thinner-bedded, and are most commonly yellow to dark brown, gray or black in color.

All sandstones of the upper part, and some of the shales of Unit 1 are said to be mineralized. Birk[9] ascribed the black color of the

9. Birk, R. A., An extension of the Pontotoc series around the western end of the Arbuckle Mountains, Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 9, No. 6, p. 983, 1925.

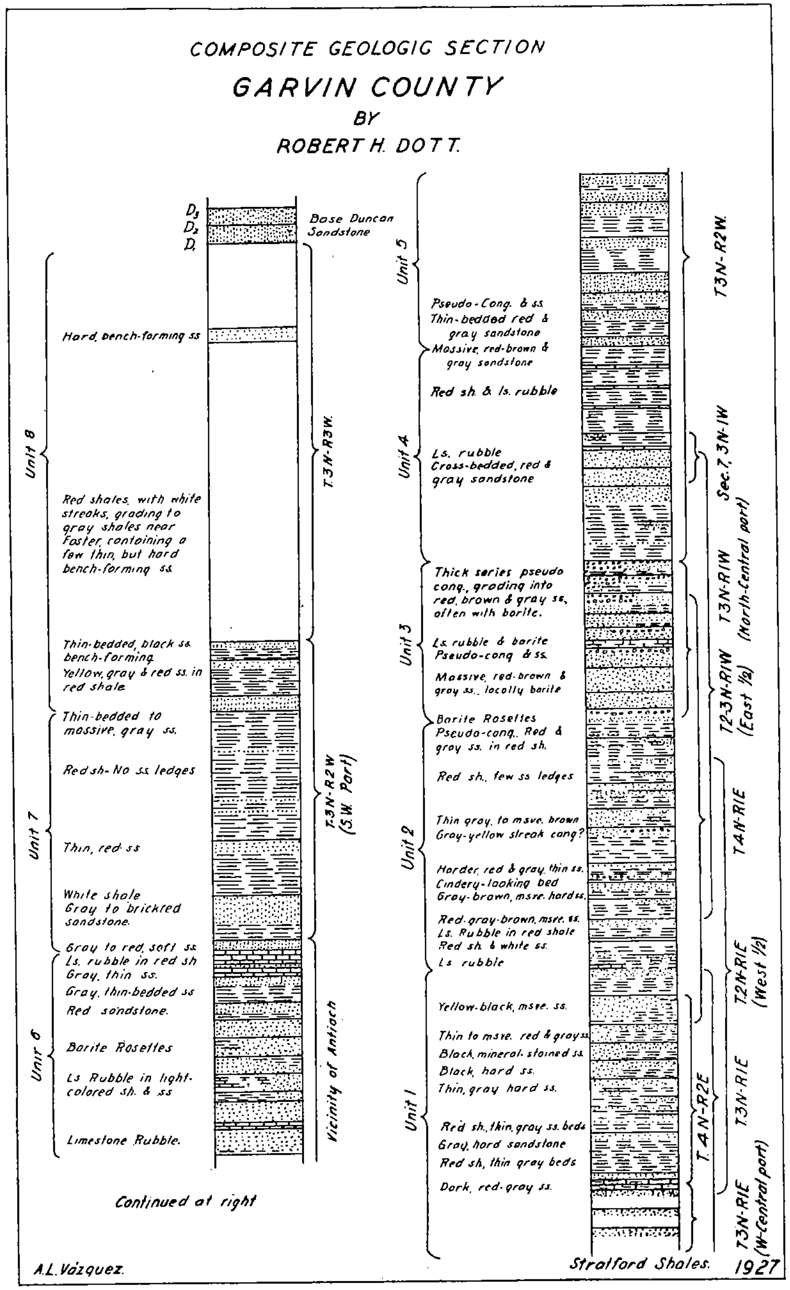


Figure 19.—Composite geologic section of Garvin County

sandstones of this unit to the presence of a manganese mineral. An abandoned mine in section 4, T. 4 N., R. 2 E. is reported to have produced silver and copper from the sandstone and shale of the upper part of the unit.

From the old mine in section 4, T. 4 N., R. 2 E. southwestward to the Washita Valley, the upper part of this unit caps a noticeable escarpment. South from Pauls Valley to the mouth of Wildhorse Creek, the high bluffs on the west side of Washita River are capped by these same beds, with the lower ones near the base of the hills. A particularly good section may be seen at the west end of the highway bridge, about 3 miles southwest of Wynnewood. A small exposure of what the writer regards as Unit 1 is to be found overlying the Strafford shales and limestones, on the south side of Wildhorse Creek, in sections 27, 28 and 34, T. 1 N., R. 1 E.

Unit 1 probably corresponds to Morgan's Asher formation[10] and to the lower part of the calcareous sandstone member of the Clear Fork-Wichita group as designated by Miser on the new Oklahoma geological map.

Unit 2

Unit 2 is composed largely of shale, with thin, laterally disappearing sandstones, a few locally massive. The topography is in general rounded, and the surface is largely prairie land. The thickness of the unit is about 145 feet.

The outcrop of Unit 2 parallels that of Unit 1, from the north county line to Wildhorse Creek, and some part of the unit very likely crops out south of Wildhorse Creek.

Unit 2 corresponds to the upper part of the calcareous sandstone division of the Clear Fork-Wichita group, as shown by Miser[11].

Unit 3

Unit 3 is predominantly a massive sandstone group, about 85 feet thick. The sandstones are red to brown in color and are quite massive, though locally they grade laterally into shale with thin gray, dark brown and black sandstone ledges. The red color, when present, helps to distinguish these sandstones from those of Unit 1.

At the base of the series, in T. 4 N., R. 1 E., a bed of barite rosette concretions occurs. This can be traced several miles southwest from section 4, T. 4 N., R. 1 E. Other, similar beds occur near the middle of the unit, near Whitebead. These concretions make fair local markers, although they sometimes have as much as 50 feet of vertical range, and are therefore confusing. Another occurrence of these rosettes was noted in Unit 6, near Antioch.

10. Op. cit., p. 141.
11. Miser, H. D., Oklahoma Geological map: U. S. Geol. Survey, 1926.

Associated, interbedded, and often intergrading with the red sandstones at the top of Unit 3 are beds of what at first glance appear to be conglomerates, but what seem rather to be sandstone with small concretions or nodules of lime, arranged in such a manner as to appear like pebbles up to three-fourths inch in diameter. These psuedo-conglomerates are fairly persistent and make good local markers. One of these beds can be found in several places in secs. 5, 6, 7, and 8, T. 4 N., R. 1 E., and near Whitebead.

Several outcrops in the vicinity of Paoli show traces of copper, and copper ore is reported to have been mined from an abandoned pit one mile east of Paoli.

Like most of the Enid sandstones, those of Unit 3 are poorly bedded. They are hard enough to make rather prominent ridges, and make up the second escarpment-forming sandstone series in the Enid group.

The outcrop of this unit can be followed with reasonable certainty from the NW. cor. sec. 4, T. 4 N., R. 1 E., southwest to the Washita Valley, then from the vicinity of Whitebead south, past Brady in T. 2 N., R. 1 W., to old Fort Arbuckle (Hoover), south of Wildhorse Creek.

Westward from Hoover to Hennepin (sec. 31, T. 1 N., R. 2 W.), occur some fine-grained, red and brown sandstones, overlying limestone conglomerate, limestone and shales of probable Stratford age. From their appearance, these beds must belong to the Enid group, and from their stratigraphic and structural relationships, to Unit 3. The dip seems to be to the north or northeast.

Good exposures of Unit 3 are to be found in the vicinity of Paoli and Whitebead, in an escarpment 1½ miles west of the SE. cor. sec. 36, T. 3 N., R. 1 W., in the ridge east and north of Brady, and in sec. 13, T. 1 N., R. 1 W.

This unit forms the lower part of Miser's red sandstone member of the Clear Fork-Wichita group.[12]

Unit 4

Unit 4 is composed of three members, two of shale separated by a sandstone member which is locally massive, but grades laterally into thin-bedded sandstones with shale partings.

A generalized section is as follows:

Generalized Section of Unit 4, Enid Group, Garvin County.

	Feet
Shale, some sandstone ledges	55
Sandstone, massive, grading to thick shale with thin sandstones	40
Shale, some sandstone ledges	30
	125

12. Op. cit.

The shales are essentially similar to those of other units of the Enid group, and need not be discussed further. The sandstones of the middle member are red, gray and black in color, and are in places, much cross-bedded. They are locally massive, or with only thin shale partings. Elsewhere the member is predominantly shale, with thin sandstone ledges. Like most of the Enid sandstones, the massive beds are rather soft, while the thinner ones are harder. Small escarpments are capped by beds of this middle member, though it can hardly be called an escarpment-forming sandstone. Near the southwest corner of sec. 34, T. 2 N., R. 1 W., a ledge shows an occurrence of what appear like rain drop impressions.

In sec. 7, T. 3 N., R. 1 W., some red and gray sandstones are so cross-bedded that local east dips seem to be evident, whereas a series of elevations on a bed of limestone rubble indicates normal west dip.

The outcrop of Unit 4 trends south through R. 1 W., from the north line of the county to Wildhorse Creek, thence west up Wildhorse Valley.

West of Paoli, the unit is composed largely of shale. The sandstones of the middle member are well developed in sec. 7, T. 3 N., R. 1 W., and sec. 12, T. 3 N., R. 2 W., where they cap escarpments. From sec. 24, T. 3 N., R. 2 W., southward, these beds can be traced, but they are thinner and less prominent, except locally, as in the northeast quarter of sec. 15, T. 2 N., R. 1 W., where sandstones are massive enough to support timber. They form a pronounced westward-dipping slope in the southwest part of T. 2 N., R. 1 W. In the south-central part of T. 2 N., R. 1 W., small escarpments are capped by several beds of this unit. On the south side of Wildhorse Creek, on top of a hill in sec. 32, T. 1 N., R. 1 W., are beds which probably belong to this unit, resting upon conglomerates of probable Stratford age.

Unit 4 is part of Miser's red sandstone member.[13]

Unit 5

Unit 4 is succeeded by a series of fairly persistent, massive, escarpment-forming sandstones, overlain by shales with a few sandstone beds, belonging to Unit 5. A generalized section is as follows:

Generalized Section of Unit 5, Enid Group in Garvin County.

	Feet
Shale, red with some sandstone beds	50
Sandstones, massive, red-brown with some shale, grading into shale with thin sandstones	40
	90

The sandstone member caps an escarpment on the east side of Washita River, in the northwest part of T. 4 N., R. 1 W. On the south side of the river, in the southeast part of T. 4 N., R. 2 W., the sandstones are thin and soft. In T. 3 N., R. 2 W., however, several of the sandstones become more massive, notably in section 2, and from section 14, southeast to the southeast corner of the township, a prominent escarpment is capped by this bed. Thence the outcrop trends southward to Katie with recognizable, though not prominent ledges.

13. Op. cit.

Nearly half of T. 1 N., R. 2 W. is covered by what are considered beds of Unit 5. Rock Creek lies in the axis of the Anadarko Basin, and the beds dip northeast and southwest into it. The upper member is there composed of more massive sandstones than in the area to the north. The uppermost ledges extend up the bed of Rock Creek as far as Elmore City.

This unit belongs to Miser's red sandstone member.[14] The lower part is the third escarpment-forming sandstone in the Enid group.

Unit 6

Overlying the shale of Unit 5 occurs another prominent sandstone series, Unit 6. The lithology of this unit varies in different parts of its outcrop. In the vicinity of Antioch, in the center of T. 3 N., R. 2 W., the unit is essentially a 120 foot bed of red sandstone. To the north and south, beyond the limits of the township, the lower 50 feet grade into shale.

The upper part of the unit caps the escarpment on the south side of Washita River, two miles east from Maysville, and also the high bluffs on both sides of Rush Creek, near Antioch. In the latter locality, the lower part of the unit is composed of bluff-forming ledges, and in several localities, of a massive bed some 30-40 feet thick. A bed of barite rosette concretions occurs at the middle of this unit, near Antioch. One outcrop was noted in the road one-fourth mile north of the Antioch store. The shales contain beds of limestone nodules.

Southward from Antioch this unit can be traced with reasonable certainty to Elmore City, retaining the massive development of the upper part all the way. Some gray beds are interspersed with the red. West of Elmore City both the sandstones and shales of the unit become gray.

Unit 6 forms the top of Miser's red sandstone member. It is the fourth escarpment-forming sandstone of the Enid group.

Unit 7

Unit 6 is succeeded by a series of shales with a few persistent sandstones comprising Unit 7, totalling some 130 feet in thickness.

14. Miser, H. D., Op. cit.

The shales are mainly red, with a few white streaks. The sandstones are thin and soft and of brick-red color. The topography is rounded, with no prominent escarpments, and the outcrop is barren of timber, except in stream courses.

The hills on the south side of Washita River from Lindsay and Erin Springs, eastward to Maysville are capped by beds of this unit. From Maysville, the outcrop trends southward, west of Antioch, to Foster in the southeast part of T. 2 N., R. 3 W., thence westward along the south line of that township, to the county line. It outcrops in a belt from 2 to 4 miles wide.

From the vicinity of Foster, westward, the color changes to gray, and the material is well-bedded. This unit is probably the base of Miser's gray sandstone member.[15]

Unit 8

Following Unit 7 occurs the uppermost member of the pre-Duncan Enid. It is composed of shale, but contains several hard sandstone ledges which cap definite escarpments, capable of being traced considerable distances. The unit is approximately 300 feet thick.

This unit begins with three hard and persistent sandstones, the upper of which caps a prominent escarpment situated in the northwest part of T. 2 N., R. 2 W., which can be traced or readily recognized as far south as Foster, and as far north as Wallville. This top bed is some 30 feet above the base of the lower one, and forms the fifth escarpment-forming sandstone in the lower part of the Enid group, and the first important one below the Duncan sandstone.

The upper part of this unit is predominantly shale, with one or two persistent, hard, well-bedded sandstones near the top. Mr. Frank C. Greene called the writer's attention to one of these beds which lies about 50 feet below the base of the Duncan sandstone. It is well-exposed in T. 2 N., R. 3 W., and makes an excellent marker.

North of the center of T. 2 N., R. 3 W., the beds of this unit are distinctly red. South of this point, and west to the county line, they all appear to be gray and form the upper part of Miser's gray sandstone member[16]. The gray color seems to be localized in the axis of the Anadarko basin. Associated with this gray color, the bedding is more regular than where the beds are typically red.

Duncan Sandstone

This bed, which is one of the best markers in the red beds series, has already been described by various authors.[17 18 19 20 21]

15. Op. cit.
16. Miser, H. D., Op. cit.
17. Wegeman, C. H., The Duncan gas field, Stephens County, Okla.: U. S. Geol. Survey, Bull. 621, II, pp. 44-45, 1915.
18. Sawyer, R. W., Areal geology of a part of Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 8, pp. 322-341, 1924.
19. Gould, Chas. N., A new classification of the Permian red beds of southwestern Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 8, pp. 317-321, 1924.
20. Gouin, Frank, The geology of the oil and gas fields of Stephens County, Oklahoma: Oklahoma Geological Survey, Bull. 40-E, pp. 16-17, 1926.
21. Aurin, F. L., Officer, H. G., and Gould, Chas. N., The subdivision of the Enid formation: Bull. Amer. Assoc. Pet. Geol., vol. 10, pp. 786-799, 1926.

In Tps. 2 and 3 N., R. 3 W., the Duncan sandstone is a hard, reddish-gray, well-cemented sandstone, and as it overlies the soft shales of the upper part of Unit 8, it makes a remarkable topographic feature in western Garvin County by capping an escarpment 150 feet high. This is known as Table Mountain.

The Duncan sandstone trends from southwest of Erin Springs, east to near Wallville, thence south to Foster, thence westward up the Anadarko basin. The formation is at least 100 feet thick.

It is worthy of note that near the axis of the Anadarko basin, the sandstone is well cemented and well bedded, is hard, and forms a prominent escarpment. Out of the basin, however, north of Rush Creek in Garvin County, and north of Washita River in McClain County, it is softer, poorly bedded and does not make a clean-cut escarpment. To the north, the color is more nearly red and less gray than in the vicinity of Foster and in practically all respects, the Duncan sandstone north of Rush Creek more closely resembles the sandstone beds of the lower Enid than the bed which caps Table Mountain.

This is the highest of the Paleozoic rocks exposed in Garvin County. It has been correlated with the middle and upper Harper sandstones of Kansas, and with the San Angelo sandstone of Texas.

CORRELATIONS

The possible correlations of the Pontotoc terrane[22] and of the subdivisions of the Enid group[23] with their equivalents in northern Oklahoma and Southern Kansas, are shown in Table I, page 132.

DEPOSITION

The Pontotoc and Enid sediments were deposited under peculiar conditions. Conglomerates and fossils suggest marine or fresh water deposition for part of the Pontotoc beds, and red beds suggest terrestrial deposition for others. The red color, prevalence of cross-bedding in the sandstones and the presence of bones[24] suggest a terrestrial origin for the Enid beds.

In the Pontotoc terrane, the water-lain deposits occur nearest the mountains, where conglomerates and limestone are found in contact with the lower Paleozoic formations, They grade northward into synchronous red beds away from the mountains.

The writer has suggested in another paper[25] that the Arbuckle uplift formed a narrow, deeply down-folded and faulted syncline,

22. Gould, Chas. N., Index to the stratigraphy of Oklahoma: Okla. Geol. Survey, Bull. 35, 1926.
23. Aurin, F. L., Officer, H. G., and Gould, Chas. N., Op. cit.
24. Dr. Case states in a personal communication, that he found in an exposure at the north edge of the cemetary, just south of Pauls Valley "two fragments of bone, water worn * * * * *. The fragments were unidentifiable." Unit 1 as defined in this paper is exposed in that locality.
25. Dott, Robert H., Notes on Pennsylvanian Paleogeography: Oklahoma Geological Survey, Bull. 40-J, 1927.

Table I. Correlations of the Pontotoc terrane and Enid group.

		Garvin County	Northern Oklahoma		Kansas
Permian (Permo-Carboniferous)	Enid (Clear Fork-Wichita) Group	Duncan sandstone	Duncan sandstone	Enid Group	Upper Harper Middle Harper
		Unit 8-500'	Hennessey shale		Lower Harper
		Unit 7-130' Unit 6-120'	Garber sandstone		
		Unit 5-90' Unit 4-125' Unit 3-85'	Wellington fm.		Wellington shale, Pearl shale member of Marion fm.
		Unit 2-145' Unit 1-140'	Stillwater fm.		Marion fm. Chase fm. Council Grove fm.
Pennsylvanian	Pontotoc Terrane	Stratford fm. Vanoss fm.	Eskridge shale Neva limestone Elmdale shale Sand Creek fm. Buck Creek fm.		Wabaunsee fm.

(known in the outcrops of lower Pennsylvanian and lower Paleozoic formations, as the Mill Creek syncline), with relative uplifts north and south of this trough. That this was deep is indicated by the fact that Pennsylvanian formations have been brought in contact with the Arbuckle limestone and it is conceivable that it was invaded by a shallow arm of the Pontotoc sea or contained fresh or brackish water lakes which received part of the Vanoss and Stratford deposits.

In a recent publication[25] the writer referred to the finding of some undetermined gastropods in the Hart limestone in sec. 31, T. 3 N., R. 4 E. These were shown to D. K. Greger, who suggested they might be fresh water forms. Later Raymond C. Moore expressed a similar opinion.

In Vanoss time, the streams were tapping the newly exposed Tishomingo granite. During this time and to a greater extent in Stratford time, large quantities of calcium carbonate were being dissolved from the exposures of Arbuckle, Simpson, Viola and Hunton limestones, carried by streams and precipitated with the muds and sands after the manner suggested by Clarke[26].

Of such probable origin were the lime nodules in the shales, the cementing material in the arkosic sandstones and the Hart and

26. Clark, F. W., The data of geochemistry: U. S. Geol. Survey, Bulletin 770, p. 555, 1924.

other limestones, though the presence of fossils in the Hart limestone indicates that it was formed in part, under normal conditions of limestone deposition. Algae may also have preciptated the calcium carbonate to form limestones, as suggested by Clarke[27]. Birk[28] found algae in some of the Pontotoc limestone.

The above interpretation would account for the presence of the water-lain deposits of Vanoss and Stratford age so close to the mountains, and the localization of the limestones in a belt not far distant from the outcrops of lower Paleozoic limestones, and the change, away from the mountains in so short a distance, to contemporaneous continental deposits like the Konawa formation in northern Pontotoc and southern Pottawatomie counties.

That at least a minor unconformity occurs between the Stratford formation and the base of the Enid group is shown by the writer's interpretation of areal geology on the south side of Wildhorse Creek, where successively younger units of the Enid group rest upon Stratford shales, conglomerates and limestones. This is further suggested by a small occurrence on the Sulphur-Stratford highway between the S. L. & S. F. Railroad tracks and the north edge of Sulphur. Red shales with limestone rubble wholly unlike the Pontotoc beds, and resembling those of the Enid group, rest upon massive limestone conglomerates of Vanoss age.

The writer has seen evidence in the dips east of Davis to show that the Mill Creek syncline and the Anadarko basin are co-extensive in this locality. The gray color and even-bedding of the shales and sandstones of Units 7 and 8, of the Enid group, and the greater hardness, gray color and even-bedding of the overlying Duncan sandstone in the Anadarko basin, near Foster, suggest that they are water-lain. If so, then it is likely that the Anadarko basin contained an arm of the sea, or fresh or brackish water lakes during part of Permian time, while terrestrial conditions prevailed elsewhere.

MESOZOIC (?) FORMATIONS

CRETACEOUS (?)

Capping the hills on the north side of Wildhorse Creek, in T. 1 N., R. 1 E. and R. 1 W., and on the hills south of Salt Creek in T. 1 N., R. 2 W., are patches of loose sand, covering outcrops of several units of the Enid group. This sand is quite unlike any of the Paleozoic deposits, though it does resemble the Tertiary Guertie sand.

In a small creek near the east line of the northeast quarter of section 16, T. 1 N., R. 1 E., this loose sand is underlain by a well cemented yellow sandstone which seems to be entirely foreign to the Enid group, and to more nearly resemble the Trinity sand as exposed south of Atoka. This sandstone is in turn underlain by blue-gray

27. Clarke, F. W., Op. cit., p. 557.
28. Birk, R. A., Op. cit.

shale, likewise different from the Enid shales, and similar to the Trinity shales as described by Bullard[29].

Just north of Whitebead, at the NE. cor. sec. 4, T. 3 N., R. 1 W., is a small exposure of well cemented, yellow sandstone conglomerate which resembles in color and cementation the Trinity (?) sandstone as exposed in sec. 16, T. 1 N., R. 1 E.

The Cretaceous age of these deposits is highly conjectural, but they seem to be distinctly different from and younger than the beds of the Enid group, and they do resemble some of the Trinity deposits.

CENOZOIC FORMATIONS

TERTIARY GRAVELS

Scattered over most of the higher hills in Garvin County, and in fact over a large part of Oklahoma, are thin deposits of smooth, rounded pebbles associated with red to brown clay and fine sand. In places, as along the highway between Stratford and Sulphur, thick beds of similar gravels occur. These deposits are usually sufficiently widespread to conceal large areas of Paleozoic outcrops. The writer has found this material covering as much as 60 per cent of the area of some townships in Garvin County.

Often small fragments of silicified wood are associated with these clays and gravels. In one locality, near the east quarter-corner of section 14, T. 2 N., R. 3 E., parts of a large tree were found. Superficially, the wood resembles that of a modern tree.

These deposits were described by Gould[30], and assigned to the Tertiary. His remarks were summarized by Bailey Willis[31].

GUERTIE SAND

In the northeast corner of Garvin County occurs an area of loose sand, overlying unconformably, beds of the Stratford formation. This was mapped by Morgan[32], and has been described by Taff[33] and Morgan[34]. It is considered an old stream deposit of Tertiary age. Similar material is found in patches from this locality, eastward as far as Pittsburg County, in a belt roughly parallel to and not far distant from the course of Canadian River. The loose sand in the southern part of Garvin County may be of similar age and origin.

29. Bullard, Fred M., The geology of Love County, Oklahoma: Okla. Geol. Survey, Bull. 33, p. 17, 1925.
30. Gould, Chas. N., Geology and water resources of Oklahoma: U. S. Geol. Survey Water-Supply Paper, No. 148, 1905.
31. Willis, Bailey, Index to the stratigraphy of North America: U. S. Geol. Survey, Prof. Paper 71, pp. 813-814, 1912.
32. Op. cit.
33. Taff, J. A., Geology of the McAlester-Lehigh coal field, Indian Territory: U. S. Geol. Survey, 19th, Ann. Rept., Part III, 1899.
34. Op. cit., p. 142.

ALLUVIUM

Recent alluvium fills the valleys of Washita River and its larger tributaries.

WIND BLOWN SAND

A deposit of fine sand can be found capping some of the bluffs on the east side of Washita River covering and concealing Paleozoic outcrops. The material is red in color, of loessial texture, and was obviously blown to its present position from the Washita flood plain, by the prevailing southwesterly winds.

Considerable areas are covered by this material north of Pauls Valley, and between Pauls Valley and Wynnewood, on the east bank of Washita River.

Similar deposits can be found in the city of Tulsa, and elsewhere along the banks of Arkansas River, as well as along the banks of all east-flowing streams in Oklahoma.

SUBSURFACE FORMATIONS

LOWER PALEOZOIC

In Pontotoc and Murray counties, east and south of Garvin, nearly all of Oklahoma's lower Paleozoic formations are exposed, including two important oil producing horizons. Here may be found the Arbuckle limestone, Simpson formation (to which belongs the Wilcox sand), Viola limestone (a minor producer), Sylvan shale and Hunton limestone (an important producer in Seminole County).

Subsurface mapping on this latter formation has shown the existence of a plunging arch[35] [36] whose axis lies in western Pontotoc County. By virtue of this Hunton Arch, the lower Paleozoic formations dip westward beneath Garvin County, and a few wells in the extreme eastern part, and in adjacent parts of Murray, Pontotoc and Pottawatomie counties have penetrated them, as shown in Table II.

In the Robberson field, T. 1 N., R. 3 W., lower Paleozoic rocks have been found beneath the red beds, dipping at high angles, on the westward extension of the Arbuckle anticline. This is fully discussed by Robert Roth (See pp. 144-164).

MARINE PENNSYLVANIAN

Structurally conformable with the lower Paleozoic formations in the Robberson field, and likewise overlapped by the red beds, occur a thick series of Pennsylvanian sediments belonging to the Glenn

35. Morgan, George D., Op. cit., p. 43.
36. Dott, Robert H., Op. cit.

Table II. Subsurface formations in eastern Garvin County

COMPANY OR FARM	LOCATION	DEPTHS			
		PENN. PERM. TO	LOWER PALEOZOIC FORMATIONS		
			Formation	From	To
Lewis	29-T 3 N., R. 4 E.	1127	Hunton Sylvan Viola—[37]	1127 1247 1300	1247 1300 1435
Dixie, Filmore	33-T. 3 N., R. 4 E.	830	Simpson	830	1320
Gilcrease	16-T. 4 N., R. 4 E.	1280	Hunton Sylvan Viola Simpson	1280 1450 1600 1990	1450 1600 1990 2267
Wrightsman	24-T. 4 N., R. 4 E.	1240	Hunton Sylvan Viola Simpson	1240 1325 1500 1930	1325 1500 1930 2756
Stuyvesant	7-T. 1 N., R. 3 E.	1380	Simpson	1380	2525
Goldeline	11-T. 2 N., R. 3 E.	760	Simpson Arbuckle	760 1720	1720 2006
Manahan	5-T. 3 N., R. 3 E.	2075	Hunton Sylvan Viola Simpson	2075 2250 2370 2920	2250 2370 2920 2924
J. S. Cosden	32-T. 3 N., R. 3 E.	1690	Simpson	1690	2005
Day Oil Co.	9-T. 5 N., R. 3 E.	3330	Hunton Sylvan Viola Simpson	3330 3466 3605 4018	3466 3605 4018 4021
Gibson	29-T. 2 N., R. 2 E.	2205	Simpson	2205	2945
Texas-Pacific	35-T. 3 N., R. 2 E.	1985	Simpson	1985	2480

formation as defined by Taff, Goldston, Girty and Roundy[38]. The possible correlations of these beds with their equivalents in other areas may be seen in Table IV. These same formations probably extend northward into Garvin County, though no drilling in the central or western part has as yet been deep enough to prove their presence.

Just east of Garvin County, in western Pontotoc, equivalents of the Glenn formation are very thin or entirely absent from the top

37. The Viola limestone listed in these tables probably includes magnesian limestone of upper Simpson age, which Luther White has designated "Post Wilcox Simpson." They are indistinguishable in well logs from the Viola limestone.

38. Taff, J. A. U. S. Geol. Survey, Geol. Atlas, Tishomingo Folio (No. 98), 1903. Goldston, W, L,, Jr., The differentiation and structure of the Glenn formation: Bull. Amer. Assoc. Pet. Geol., vol. 6, 1922. Girty, George H., and Roundy, P. V., Notes on the Glenn formation of Oklahoma with consideration of new paleontologic evidence: Bull Amer. Assoc. Pet. Geol., vol 7, pp. 331-349, 1923.

of the Hunton Arch[39]. Where present, they rest unconformably on the lower Paleozoic formations. They are in turn disconformably overlain by a thin layer of fossiliferous shale thought to belong to the Ada formation (of Wabaunsee age), which overlaps still further toward the top of the Hunton Arch, covering still older formations. This is immediately succeeded by the conformable beds of Pontotoc age.

In Garvin County, marine Pennsylvanian strata have been found beneath the red beds in the following wells, in addition to those listed in Table No. II:—

Table III. Wells in Garvin County and vicinity which have passed through red beds into marine Pennsylvanian strata.

Company	Location
Detert	Sec. 10, T. 6N., R. 2 E. [40]
Texas Pacific	Sec. 5, T. 1 N., R. 1 E. [40]
Sinclair	Sec. 23, T. 4 N., R. 1 E.
Thompson	Sec. 36, T. 5 N., R. 1 E.
Empire	Sec. 27, T. 2 N., R. 1 W. [41]
Barber	Sec. 30, T. 2 N., R. 1 W. [41]
Nelson et al	Sec. 21, T. 4 N., R. 1 W. [40]

The fact that some of these wells are over 3,000 feet deep and show a considerable thickness of material below the red beds, without having reached lower Paleozoic formations, indicates that in Cherokee, Marmaton and Kansas City time, a basin similar to the Coal Basin existed to the west of the Hunton Arch and received sediments of similar thickness. These thick Pennsylvanian sediments must therefore be present beneath central and western Garvin County.

The above is the extent of our present knowledge of the subsurface stratigraphy of Garvin County, outside the Robberson field. It is to be hoped that in future deep drilling, cuttings will be carefully taken and examined microscopically, in order that some definite information may be obtained.

Table No. IV lists the formations thought to be present beneath the surface of Garvin County, and their probable equivalents in other areas.

39. Dott, Robert H., Op. cit.

40. The writer saw fossils from these wells.

41. There is some doubt as to the identity of the lowest formations.

Table IV. Subsurface stratigraphy of Garvin County with correlations.

Age	Northern Oklahoma and Kansas	Garvin County and vicinity	Carter County
Permian	Enid group	Enid group	Enid group
Pennsylvanian	Wabaunsee	Pontotoc terrane Ada formation	Pontotoc
	Shawnee	Vamoosa	Break ?
	Douglas	Break ?	Break ?
	Lansing	Break ?	Break ?
	Kansas City	Francis	Hoxbar
	Marmaton	Wetumka-Seminole	Deese (Glenn[42])
	Cherokee	Thurman-Calvin Savanna-Boggy	Cup Coral
	Winslow	Absent (?) in Garvin Co.: McAlester Hartshorne	? ?
	?	Atoka	?
	Morrow formation	Wapanucka Upper Caney	Otterville Springer
Mississippian		Lower Caney Sycamore	Caney Sycamore
Devonian		Woodford Upper Hunton	Woodford Upper Hunton
Silurian		Lower Hunton Sylvan	Lower Hunton Sylvan
Ordovician		Viola Simpson Upper Arbuckle	Viola Simpson Upper Arbuckle
Cambrian		Lower Arbuckle Reagan	Lower Arbuckle Reagan

42. True Glenn, according to Girty and Roundy. Goldston would include the Springer, Otterville, Cup Coral, Deese and Hoxbar.

THICKNESS OF RED BEDS

Plate III shows the thickness of the red beds in Garvin County and parts of adjacent counties. Included in these "red beds" are the "red Pennsylvanian" (Pontotoc terrane) and the Permian (Enid group). Whether the base of these red beds represents the same stratigraphic horizon in all cases is conjectural.

Most of the wells in this vicinity were drilled with rotary tools, and many of the logs are so poorly kept that only a few selected ones could be used for this map. Many logs of deep wells report no "red beds" at all.

It is interesting, though beyond the scope of this paper, that in many of the Carter and Stephens County pools, the red beds are thinner than outside the pools, indicating that these fields overlie buried hills which were islands during part of red bed deposition. As this map is generalized, these features are not well shown. Burton[43] has worked out the details of this relationship for several fields.

STRUCTURE

SURFACE STRUCTURE

Two major structural features occur in Garvin County, the Anadarko basin and the Arbuckle anticline. The short south limb of the former is also the north limb of the latter, whose extension in Garvin County is largely buried beneath red bed deposits. The Anadarko basin is a depositional feature, resulting largely from settling into a pre-existing trough. The Arbuckle anticline is clearly the result of horizontal movement.

Since Garvin County is topographically a dissected plateau with the tops of the hills always at about the same level, the areal geologic map serves also to show the regional surface structure.

A number of small apparent domes and anticlinal noses can be worked out in various parts of the county, but from the nature of the beds and the absence of good markers, such mapping is attended with considerable uncertainty.

SUBSURFACE STRUCTURE

Outside the Robberson field, our knowledge of the subsurface structure of Garvin County is limited to the extreme eastern part where wells have passed through red beds and marine Pennsylvanian strata into lower Paleozoic formations. These data indicate only that eastern Garvin County lies on the steep west flank of the Hunton Arch, as shown by figure 20.

The Texas Pacific Coal and Oil Company well in sec. 5, T. 1 N., R. 1 E., (T. D. 3,476 feet, in Pennsylvanian) and the Sinclair Oil

43. Burton, George E., Relation of red beds to the oil pools in a portion of southern Oklahoma: Bull. Amer. Assoc. Pet. Geol., vol. 5, p. 173, 1921.

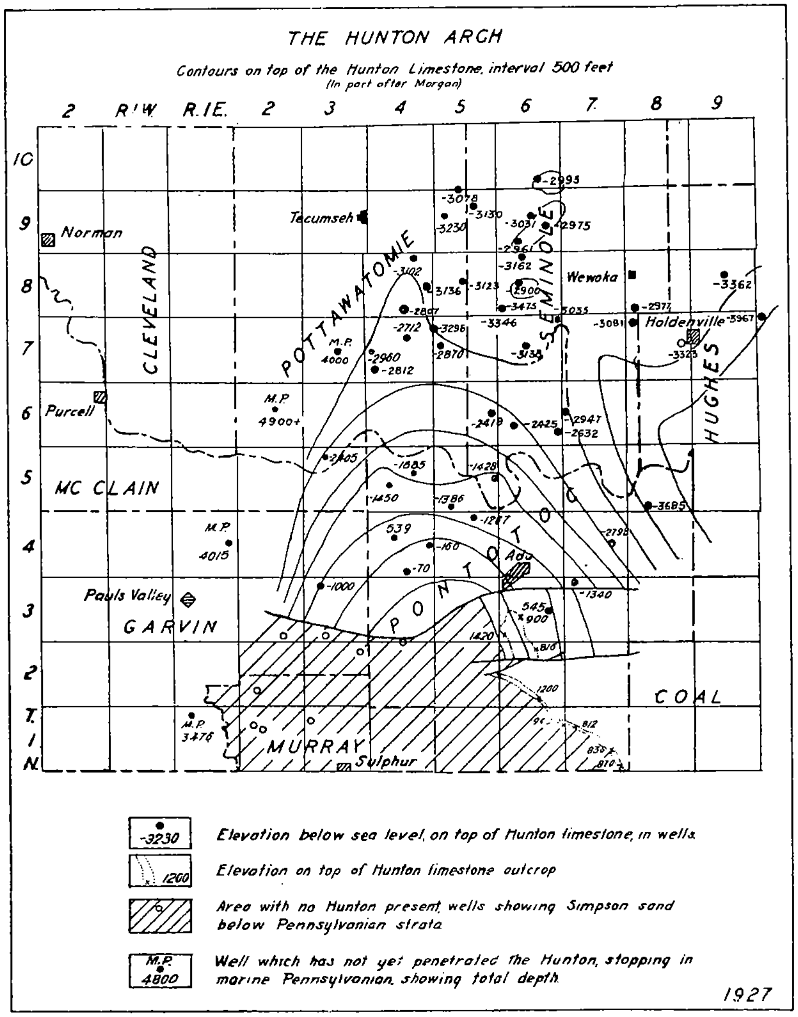


Figure 20.—The Hunton Arch.
N. B. for well in sec. 10, T. 6 N., R. 2 E., read 4,900 instead of 4,015.
Well shown in sec. 33, T. 5 N., R 9 E., should be in 33, T. 5 N., R. 8 E.

and Gas Company well in sec. 23, T. 4 N., R. 1 E. (T. D. 4,015 feet, in probable Pennsylvanian) indicate that the lower Paleozoic formations are dipping rapidly to the westward. The Texas Pacific well showed upper Pennsylvanian at an elevation of 2,480 feet below sea level at the bottom of the hole, whereas the Gibson well seven miles east showed the top of the Simpson sand at 1,417 feet below sea level. The Sinclair well showed Pennsylvanian at about

3,015 feet below sea level at the bottom of the hole, whereas the G. A. Manahan, well nine miles east, showed the Hunton limestone at 994 feet below sea level.

The top of the Hunton Arch has been broken by a fault parallel to the Arbuckle anticline and the Mill Creek syncline, through the southern part of T. 3 N. The upthrow is to the south, bringing the Simpson formation in contact with the Hunton limestone. This fault is shown on Fig. 20. Table V shows several wells in which the Simpson formation was found to be overlain by marine upper Pennsylvanian strata. Wells drilled north of this fault found these younger deposits to be overlying the Hunton limestone.

Table V. Wells showing Simpson sand to be overlain by marine Pennsylvanian strata.

Company	Location	Depth to Simpson Sand
Dixie Oil Co.	sec. 33, T. 3 N., R. 4 E.	830 feet
Goldeline Oil Co.	sec. 11, T. 2 N., R. 3 E.	725 feet
J. S. Cosden	sec. 32, T. 3 N., R. 3 E.	1,690 feet
Texas Pacific	sec. 35, T. 3 N., R. 2 E.	1,985 feet

The fault block described above probably extends westward for some distance, but the relation of the subsurface formations in the Gibson well in sec. 29, T. 2 N., R. 2 E., and the Texas Pacific well in sec. 5, T. 1 N., R. 1 E., indicates that it is plunging rapidly to the west.

FUTURE POSSIBILITIES

In the present state of our knowledge, the future of Garvin County as an oil producer is an enigma. In January, 1927 a new pool was opened south of the Robberson field, and others may yet be found in that vicinity. Outside the Robberson field drilling to date has proved but little beyond the thickness of the red beds and the certain fact that any future production will be deep.

It seems reasonable to expect that any possible production should be found under conditions similar to those existing in neighboring oil fields. Five sets of such conditions are known:—

1. Pennsylvanian production near Ada.
2. Hunton and Wilcox production in Seminole County.
3. Production in Carter and Stephens counties.
4. Ordovician production at Robberson.
5. Permian (?) production in T. 3 N., R. 5 W.

PENNSYLVANIAN PRODUCTION

Wells have produced small quantities of oil from the Boggy shales (Cherokee) or adjacent formations in the vicinity of Ada and Allen. This production occurs in small flexures of otherwise gently dipping beds.

Similar beds, probably under similar structural conditions occur in Garvin County, though at prohibitive depths unless larger wells can be found than those in the Ada and Allen fields.

HUNTON AND WILCOX PRODUCTION

A small amount of production is found in the Hunton limestone near Beebe, Pontotoc County, and a commercial well was completed in January, 1927, producing from this horizon, in sec. 19, T. 7 N., R. 4 E. The discovery wells in the Seminole field produced from the Hunton horizon, and numerous Hunton wells are still being operated.

Scores of wells in Murray and Pontotoc and a few in Garvin County have passed through the Hunton limestone with no more than small showings of oil.

In eastern Garvin County on the west flank of the Hunton Arch, the Simpson formation of which the Wilcox sand is a member, contains sulphur water. Numerous wells in Pontotoc and Murray counties prove that this formation will not be likely to contain oil in areas where artesian water is present.

Since the Hunton limestone and older formations are dipping so steeply to the west on the flank of the Hunton Arch, they are not likely to contain oil nor to be within reach of the drill unless folding of great magnitude has elevated them, a condition for which there is not the slightest suggestion of evidence.

PRODUCTION IN CARTER AND STEPHENS COUNTIES

South of the Arbuckle anticline occur a number of oil fields, whose production seems to have originated in Carboniferous (Caney and Glenn) and older formations, from which it has migrated along highly tilted bedding planes, to accumulate in sands of the unconformably overlying red beds, which were flexed over topographic highs in the older formations, during or following deposition.

Wells drilled into the Carboniferous formations where they are flat-lying and not covered by red beds have produced little or no oil, suggesting that tilting and red beds overlap are responsible for the accumulation.

Such conditions cannot be found in Garvin County, outside the vicinity of the Robberson field, and the finding of Pennsylvanian shales beneath red beds in all wells west of R. 2 E., where any sort of determination can be made, and the lack of success in drilling indicate that they do not exist.

ORDOVICIAN PRODUCTION AT ROBBERSON

It will be shown in Mr. Roth's paper that in the Robberson field the Ordovician formation seems to be the most logical source-rock for the oil which has accumulated in the axis of the Arbuckle anticline.

Reasons have already been given to show that Simpson production cannot be expected in eastern Garvin County, at least unless folding of great magnitude exists both to form a suitable trap, and to bring the formation to within reach of the drill. Similar objections may be raised concerning the duplication of Robberson conditions, and there is even less reason to believe that suitable structural conditions exist north of the Arbuckle anticline.

PERMIAN (?) PRODUCTION IN T. 3 N., R. 5 W

In the Carter-Knox pool, in T. 3 N., R. 5 W., and elsewhere in that vicinity, oil is found at about 1,500 feet, in a sand which probably belongs to the red beds series. The Chickasha gas sand may occur at about the same horizon. Above this producing horizon, in T. 3 N., R. 5 W., occur several hundred feet of gray shale. Below the gray shale, and including the producing sand, red beds continue to the bottom of the deepest wells, some 3,500 feet in depth.

Obviously the oil is well up in the series and not at the base of the red beds. It may have originated in the gray shale, which appears to be an intercalated marine formation, or it may have been of deep-seated origin, having found its present accumulation by upward migration along fault planes. Neither hypothesis is supported by very strong evidence.

If the former explanation is correct, some hope might be held for similar production in Garvin County, though it seems that sufficient wells have been drilled to prove its non-existence. There is some reason to believe that the gray shale outcropping near Foster is equivalent to the gray shale found in wells.

If the latter hypothesis truly explains the accumulation, similar conditions might be found in Garvin County, after a thorough study of the Carter-Knox pool has shown what those conditions actually are.

THE ROBBERSON FIELD, GARVIN COUNTY

By

Robert Roth

INTRODUCTION

The Robberson oil field with an average daily production in June, 1923, of 6,482 barrels per day from 148 wells, ranked fifth among the producing fields of southern Oklahoma. Since then it has steadily declined, even though there has been an increase in the number of producing wells, until its average daily production for the month of December, 1926, is 2,976 barrels per day from 232 wells.

The pool has been very extensively drilled, but in spite of this fact, very little is known of the sub-surface conditions below the base of the Permo-Pensylvanian red beds, due without a doubt, to the fact that well cuttings were not saved except in a few rare occasions. However, a few more facts have been brought to light from the drilling records of the past three years which may be of some interest and which will be set forth in this paper.

ACKNOWLEDGMENTS

The writer wishes to express his thanks to the Atlantic Oil Producing Company for the liberal use of their samples, maps and production reports and to E. D. Luman for many helpful suggestions and for critically reading the manuscript. He is also indebted for many helpful suggestions to Frank C. Greene, of the Skelly Oil Company, George S. Buchanan, of the Carter Oil Company, and Sidney Powers, of the Amerada Petroleum Corporation.

The author finally records his grateful appreciation of the help of A. R. Denison in reading the manuscript and for the use of several samples of well cuttings which Mr. Denison obtained from the Amerada Petroleum Corporation. In this is included Robert H. Dott of the Mid-Continent Petroleum Corporation, who suggested many corrections and to whom the author is indebted for the inception of the manuscript.

LOCATION

With the exception of several small wells which are distant outliers of the pool, the main field lies in sections 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 and 20, T. 1 N., R. 3 W., of the southwest corner of Garvin County. It is 28 miles southwest of Pauls Valley, 30 miles east of Duncan, and 10 miles northwest of the western end of the Arbuckle Mountains. Robberson field may be reached by roads from

1. Presented before the Tulsa Geological Society, February 19, 1927.

Pauls Valley, Wynnewood, and Duncan. The nearest railroad point is Wynnewood, 22 miles northeast, on the main line of the Gulf, Colorado and Santa Fe Railway.

HISTORY

This region about Robberson field has been considered to have petroleum possibilities for the past twenty-six years. Mr. G. H. Eldridge[2] noted several occurrences of asphalt and a number of oil seepages in water wells, springs and prospect holes from the western end of the Arbuckle Mountains out as far as the Robberson field as it is now located.

Mr. Joseph A. Taff[3] has described the geography, physiography, and general relations of the Pre-Cambrian igneous rocks, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Cretaceous rocks and Quaternary deposits. He also gives the geologic structure of the Arbuckle Mountains and their mineral resources.

Mr. Chester A. Reeds worked in the Arbuckle Mountains after Joseph A. Taff. The results of this research was published as Bulletin No. 3 of the Oklahoma Geological Survey in 1910. It is entitled "A Report on the Geological and Mineral Resources of the Arbuckle Mountains, Oklahoma." In this paper Mr. Reeds describes the physiography, stratigraphy, structure and mineral resources of the region.

Another article published by Mr. Chester A. Reeds, upon the Arbuckle Mountains is to be found in Natural History, Vol. XXVI, No. 5, for September-October, 1926, and Oklahoma Geol. Survey, Circ. No. 14, 1927. This article deals principally with reminiscenses of the author while collecting in the area. The article is well illustrated and contains a good stratigraphic column which has several new revisions as well as a new formation; i. e. the Frisco limestone, which lies above the Bois D' Arc limestone and below the Woodford chert.

Taff[4] describes the physiographic features and the history of the region; the occurrence, character, and relations of the pre-Cambrian igneous rocks, and Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Cretaceous sedimentary rocks, and the geological structure of the Arbuckle and Wichita Mountains.

In 1913, L. C. Snider[5] wrote a report giving a brief discussion of all the larger deposits of asphalt found in the state of Oklahoma, which included character, size, age of containing rocks and location.

2. Eldridge, G. H., U. S. Geol. Survey, 22nd Annual Report, 1901.
3. Taff, Jos. A., U. S. Geol. Survey, Geol. Atlas, Tishomingo Folio (No. 98), 1903.
4. Taff, Jos. A., Preliminary report on the geology of the Arbuckle and Wichita Mountains, in Indian Territory and Oklahoma: U. S. Geol. Survey, Prof. Paper, 31, 1904.
5. Snider, L. C., Rock Asphalts of Oklahoma and their use in Paving: Oklahoma Geol. Survey, Circ. No. 5, 1913.

Several deposits in counties surrounding the Robberson field were mentioned.

In 1915 Pierce Larkin confirmed the presence of oil and gas in shallow water wells at Robberson, two of which are in the NE. ¼ sec. 16, T. 1 N., R. 3 W. He also found evidence of favorable structure in local dips. On his recommendation a block of acreage was secured by the McMan Oil Company, who sold their holdings to the Magnolia Petroleum Company before the leases were prospected. It is probably due to his work that the field was discovered.

Moore[6] gives a general discussion of all the principal producing fields of southern Oklahoma, south and west of the Arbuckle Mountains which contains a study of the subsurface conditions of the fields and their intimate relationship to the Arbuckle uplift.

A brief discussion of the geological history of the region and facts regarding the origin of the oil are put forth. It is believed that most of the oil in southern Oklahoma is derived from the Ordovician.

No further work was published on the area in general until Mr. W. L. Goldston, Jr.[7] described the Glenn formation as including the Hoxbar, Deese, Cup Coral, Otterville and Springer members, also giving character, areal extent, faunal lists and a correlation with north-central Texas and with the formations north of the Arbuckle Mountains.

Following this article Girty and Roundy[8] published an article giving faunal lists of all the members of the Glenn formation as well as some members northeast of the Arbuckle Mountains with which the Glenn has been correlated. From these results and by taking the original definition of the Glenn as given by Taff in the Tishomingo Folio, they believe they have grounds for delimiting the Glenn formation to the Deese, Cup Coral and possibly the Otterville members.

A report by A. R. Denison[9] summarizes all the data that was known about the Robberson field up to that time.

The last publication on the area in general is in the Bulletin of the American Association of Petroleum Geologists, Vol. IX, Number 6, for September, 1925.

Ralph A. Birk[10] traced the limestones near the base of the Stratford formation of the Pontotoc series around the west end of the

6. Moore. R. C., The relation of mountain folding to the oil and gas fields of southern Oklahoma: Bull. Amer. Assoc. Pet. Geol., Vol. 5, No. 1, 1921.
7. Goldston, W. L. Jr., Differentiation and structure of the Glenn formation: Bull. Amer. Assoc. Pet. Geol. Vol. VI, No. 1, 1922.
8. Girty, Geo. H. and Roundy, P. V., Notes on the Glenn formation of Oklahoma, with consideration of the new paleontologic evidence: Bull. Amer. Assoc. Pet. Geol., Vol. VII, No. 4, 1923.
9. Denison, A. R., The Robberson field, Garvin County, Oklahoma: Bull. Amer. Assoc. Pet. Geol. Vol. VII, No. 6, 1923.
10. Birk, R. A., The Extension of a portion of the Pontotoc Series around the western end of the Arbuckle Mountains: Bull. Amer. Assoc. Pet. Geol., Vol. IX, No. 6, 1925.

Arbuckle Mountains, and then southeast to a point near Ardmore. The mapping was done before George D. Morgan's report on the geology of the Stonewall quadrangle was published. Since the top, rather than the bottom, of the limestone series was followed the line shown on the map does not coincide with the one of Morgan's formation boundaries. The base of the Asher formation, which is next above the Pontotoc series, was also traced around the mountains and found to overlap the shale in the upper part of the Stratford formation. The west end of the Asher formation rests directly on the limestones in the lower part of the Stratford formation, which are in contact with the upturned edges of the Ordovician limestones. All lower members of the Pontotoc series are absent. The conglomerates near Berwyn, formerly called Franks, are assigned to the Pontotoc series, and a correlation is made across the mountains by J. T. Richards on the basis of some concentric-ringed pebbles which have been banded by algae. It is suggested that the uncertain boundary between the Permian and Pennsylvanian be placed at the base of the Asher formation.

Gas was discovered in April, 1920, by the Magnolia Petroleum Company, Cowan No. 1, NW.¼ SW.¼ NW.¼ sec. 16, T. 1 N., R. 3 W., and became exhausted before the well was completed. The first big well to be brought in was the Mauldin No 1, which came in on June 9, 1920, estimated at 40,000,000 cubic feet from a total depth of 1,386 feet.

Following this an active campaign was started on adjacent property and during the next thirteen months many gas wells were completed in sections 15 and 16. Most of them reached the gas sand of the Mauldin No. 1.

Oil was discovered in Magnolia's Hart-Newberry No. 1 in the NW. cor. section 14 on July 16, 1921, more than a year after the discovery of gas. This well was estimated to have yielded 200 barrels per day and stimulated a drilling campaign which led to the finding of oil in section 16, and in the vicinity of the discovery well in section 15. Development progressed around these centers of production until they were connected by producing oil wells.

The first large producer was the Texas-Pacific Coal and Oil Company's Pearce No. 1, NE.¼ SW.¼ sec. 13, which came in on August 16, 1922, producing 1,000 barrels daily (initial yield). This well gave the field its greatest impetus and there soon followed two other wells, each making more than 8,000 barrels daily. From that time on the production increased very rapidly, reaching its peak in less than a year from the initial discovery. Since then the field has steadily declined to its present production.

STRATIGRAPHY

SURFACE

The surface exposures of the Robberson field are all of Permian age. They consist of alternating shales and sandstones, the latter sometimes grading into conglomerates, and one or two thin limestone beds. The shales are largely brown and red with an occasional blue or gray bed which rapidly grades into the characteristic red-brown shales. The sandstones frequently contain crystals of pink potash feldspar, and when these sandstones are weathered they have a spotted appearance due to the oxidation of the iron pyrite which they contain. The conglomerates contain fragments of granite porphyry and a very coarsely crystalline granite made up of quartz and the above mentioned pink orthoclase. This igneous material has been derived from granite porphyry and Tishomingo granite, which is now cropping out about 12 miles to the southeast, and is probably of Archean age. In Denison's report on the area mention is made of a bituminous sandstone cropping out in section 24 and another in the SE. cor. section 16.

SUBSURFACE

Permian

In general the first 1,200 feet encountered by the drill are in part red beds called gumbo, gravel composed of arkosic material, and several limestone beds, one of which, occurring from 950 to 1000 feet, is recorded in most of the early wells drilled. This series has been named the Garvin beds by Mr. Denison. The Garvin beds carry a few water sands near the surface and these sands have a good supply of meteoric water. The lower sands of the Garvin beds contain little water, but they do have an occasional show of heavy oil. At the base of this formation is a fairly continuous limestone bed which serves as a cap rock to the producing horizon and it is upon this limestone that the contours have been made which served as the datum plane from which the profile in Figure 21 was drawn.

This figure is drawn through the high in section 14, and shows the relative accumulation of oil and gas in the Newberry sands and in the Ordovician. The formations penetrated are drawn with a scale of three on the vertical to one on the horizontal.

From 1,200 to 1,600 feet occur a series of gas sands alternating with red, brown and blue shales, which in Denison's report are called the Mauldin producing horizon after the original large gas well, Mauldin No. 1. The sands are quite lenticular which makes correlation almost impossible, even in offset wells. This apparent lenticular character of the gas sands may in part be due to faulting or slumping in the Permian. Wells to the west of the discovery well encounter three gas sands which are fairly continuous; however, the lowest is the most prolific and is the one to which most of the later wells have been drilled. In the eastern part of the field adjacent to the dis-

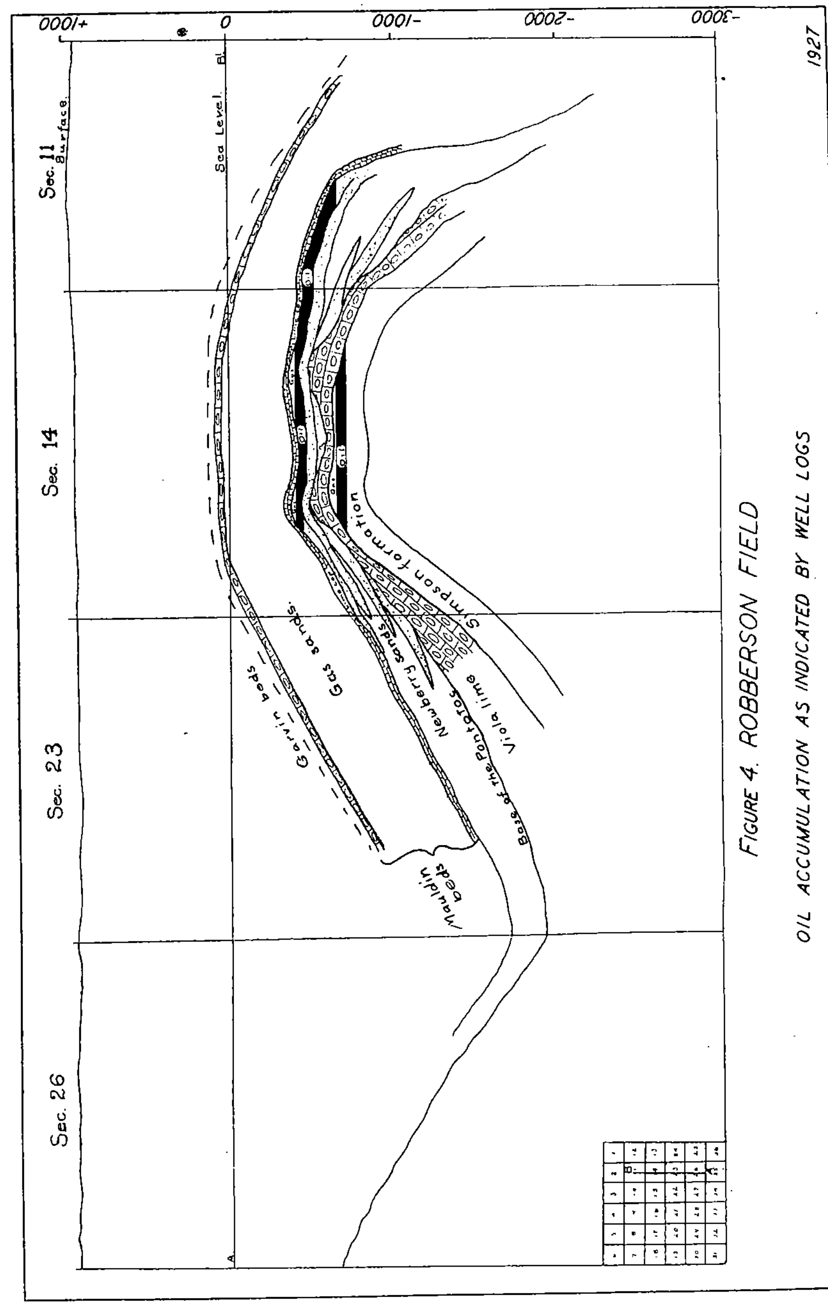


Figure 21.—Cross-section of the Robberson field.

covery well only one gas horizon has been recognized. It is quite persistent and can be roughly contoured within the limits of its production. Samples of this sand show it to be composed of well-rounded quartz grains which are frosted. They are identical with the Ordovician sands and have been derived from the Simpson formation cropping out in the Arbuckle Mountains to the southeast.

PENNSYLVANIAN

The Garvin and Mauldin beds are of Permian age and both rest with great unconformity upon the Ordovician sediments below, since all the Silurian, Devonian, Mississippian, and most of the Pennsylvanian have been removed, as well as a part of the Ordovician. In the old ravines and gullies of these buried hills, and also spread over the hills themselves at a depth varying from 1,375 to 1,877 feet is found a sand series called in Denison's report the Newberry sands after the discovery well, Newberry No. 1. These sands are undoubtedly an erosional residue and probably represent an overlap of the last of the Pennsylvanian seas in the area prior to Permian deposition, as they may be correlated with the Pontotoc cropping out to the southeast. Certainly there can be but little doubt that they represent a formation older than the Permian.

ORDOVICIAN

The buried hills are composed of a series of limestones and sandstones with a limestone layer of varying thickness over the top. These formations are resting at a high angle probably as a monoclinal fold with the steepest dip to the north and, without a doubt, are faulted. A steep dip on the north would account for the undue thickness of limestone encountered in some of the wells drilled on that flank.

Well samples of this limestone have been examined with the microscope and were found to vary in color and lithographic character from a dense light brown to a dark gray limestone containing some crystalline calcite stringers of almost microscopic dimensions. Larger fragments show many calcite stringers running through the mass and this is also well brought out in thin sections of the limestone. No dolomite has been identified in this limestone. These well samples were compared with outcrop samples of Viola and Arbuckle limestones and seem to agree in every way with the characteristics of the Viola limestone as examined, but do not seem to check with the Arbuckle limestone. Furthermore, the section below the limestone in question is comparable to the Simpson formation. Typical Simpson sands which are present would exclude the probability of the limestone beds as being a part of the Arbuckle limestone. From these facts it seems that the limestone is Viola and the alternating sands and dolomitic limestones are Simpson and that the Arbuckle limestone has probably never been penetrated by the drill in the Robberson field.

In Mr. Denison's report two wells in particular were stated to have penetrated granite. One of these wells is the R. Newberry No. 2, Acc. No. 2 of the Texas-Pacific Coal and Oil Company, 150 feet from the SE. line SW.¼ NE.¼ SW.¼ sec. 13, T. 1 N., R. 3 W., in which the granite was logged by the drillers as red and black limestone from a depth of 1,801 to 2,119 feet.

The other well which reported igneous material is the Weaver No. 1, NE. cor. W.¼ SE.¼ SW.¼ sec. 13, T. 1 N., R. 3 W., Texas-Pacific Coal and Oil Company. This well was shut down at 1,805 feet in what was logged as black limestone. Samples of this black limestone are described as dark porphyry in Denison's report.

Figure 22 is a contour map based upon the contact between the Pontotoc and the Ordovician. The contours in this map are quite accurate as there is no doubt as to the formation when the drill strikes the Viola limestone. The probable faulted zone is indicated by one line. Contour intervals are 100 feet, and areas which have an accumulation of oil and gas are indicated. The dark circles are wells penetrating the Ordovician and the depths at which the Ordovician was encountered is given, taken from sea level as a base. The light circles are some of the deeper wells in the red beds. Shallow depths are not given but were used as control points in making sub-surface contours.

In referring to Figure 22 it will be noted that the Viola limestone has been found within a quarter of a mile on all sides of these two granite wells. Furthermore, it can be noted that the total depth of these wells is about where the base of the Pontotoc should be as there is a small depression found at this place.

Samples of the granite found in the R. Newberry No. 2 were examined by the writer and found to be arkose. Since the arkose found in this area resembles a granite to such an extent that when it is drilled up, it is impossible to differentiate it from a true granite without the aid of a microscope, hence it is very possible to mistake this arkose for a granite. Samples of the Weaver No. 1 were not obtainable, but Sidney Powers states that the material is a diorite or a related rock. If this is so and if the writer's determination of the Viola limestone is correct, then it is the first instance of igneous activity later than the pre-Cambrian so far found in the Arbuckle Mountains.

The areal geologic map (Fig. 23) shows the Arbuckle uplift and its relationship to the pools southwest of the Arbuckle Mountains. The condition at Robberson is indicated as being a continuation of the Arbuckle uplift beneath the red bed overlap, and it will be noted that the other pools have a tendency to be en echelon and parallel to the main uplift. The subsurface formation contacts are indicated and are quite accurate, except northeast and due east of the Robberson field as no deep wells have been drilled in this area. The formation

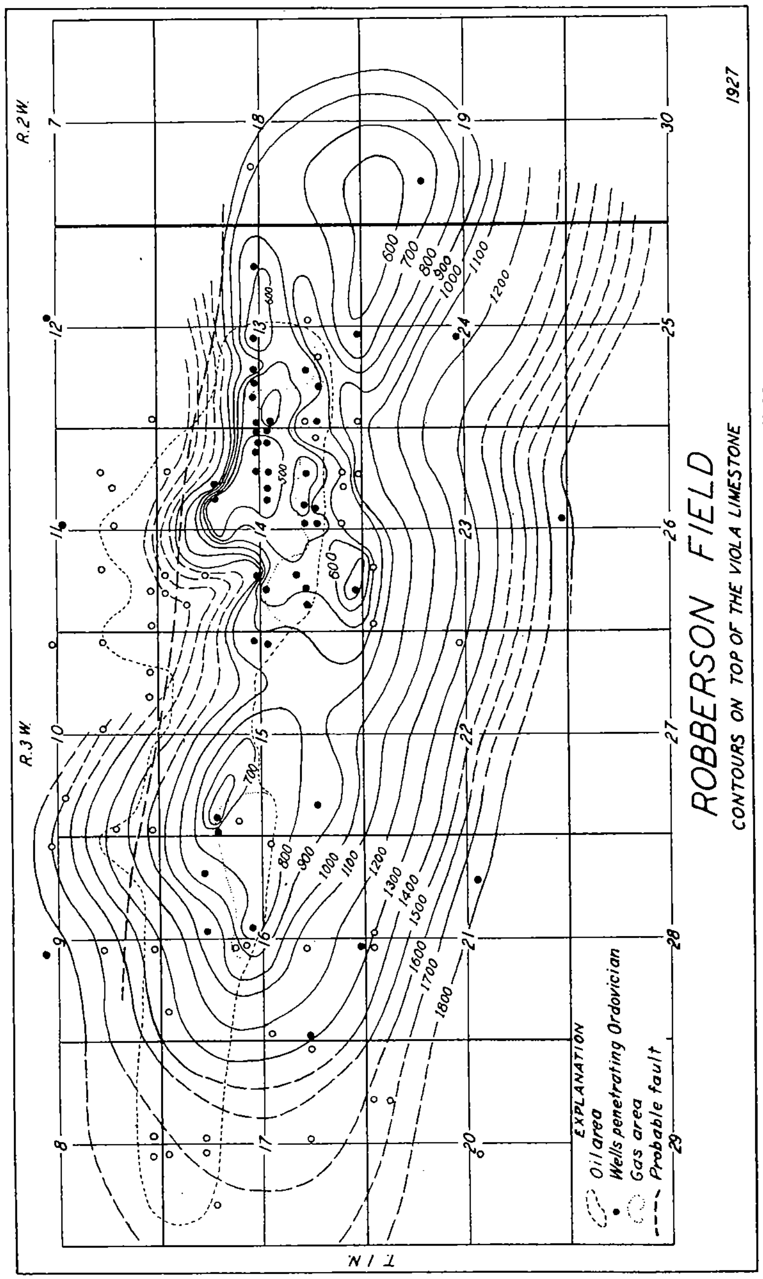


Figure 22.—Contour map of the Robberson field.

contacts south and southeast of Robberson beneath the red beds overlap are based upon sample determinations of the following wells.

Samples obtained from the wells drilled on the south flank of the pool were examined with a microscope and these determinations were made with the aid of microscopic fossils. Broadgate's Abram No. 1, SW.¼ SE.¼ sec. 23, T. 1 N., R. 3 W., passed through the red beds at 1,295 feet and entered into a formation that is Springer or older, and encountered the Viola limestone at 2,910 feet. The well was abandoned at 3,016 feet, still in the limestone. Magnolia's Downey No. 1, NE.¼ NE.¼ sec. 22, T. 1 N., R. 3 W., found the base of the red beds at 1,825 feet and penetrated the Springer to 2,480 feet, the total depth. Another well, W. H. Riddle No. 1, Texas-Pacific Coal and Oil Company, SW.¼ SW.¼ NW.¼ sec. 35, T. 1 N., R. 3 W., had the base of the red beds at 584 feet and then went to 2,630 feet, ending in definite Springer. The Magnolia Burr No. 1, sec. 31, 1 N., R. 3 W., produced 75 barrels per day (initial production) after being drilled in late January, 1927. Samples were examined from a depth of 3,390 feet and the fauna which they contained indicated that the production was coming from the Cup Coral.

On the west side of the pool the section is best represented by the Edwards No. 1, Grimes and Russell, sec. 23, T. 1 N., R. 4 W. This well found the base of the red beds at 1,968 feet. It drilled to a total depth of 3,525 feet, ending in the Deese member of the Glenn formation.

On the north side of the pool, the well in the NW.¼ SE.¼ SE.¼ NW.¼ sec. 9, T. 1 N., R. 3 W., found the base of the red beds at 2,745 feet. It then penetrated the Viola limestone to a total depth of 4,275 feet. Other wells to the north of the pool have very unsatisfactory logs and interpretation is impossible. One log, however, is fairly good. It is that of the Bell No. 1 Shaffer, located in the SE.¼ SE.¼ SE.¼ NW.¼ sec. 33, T. 2 N., R. 3 W., in which the red beds were penetrated to a depth of 2,005 feet. The base of the red beds north of the field is below 3,000 feet.

On the east and southeast all the older formations gradually come to the surface until they crop out about twelve miles distant from the field in the Arbuckle Mountains.

OIL PRODUCING SANDS

PONTOTOC

Samples from the Newberry sands with few exceptions are shown to be but loosely consolidated sediments, composed of conglomerates, containing some fragments as large as hazel-nuts, and consisting of chert, limestone, crystalline quartz, and pink potash feldspar. Some fragments are angular and others well rounded. In general, the limestone is well rounded, while the chert and larger

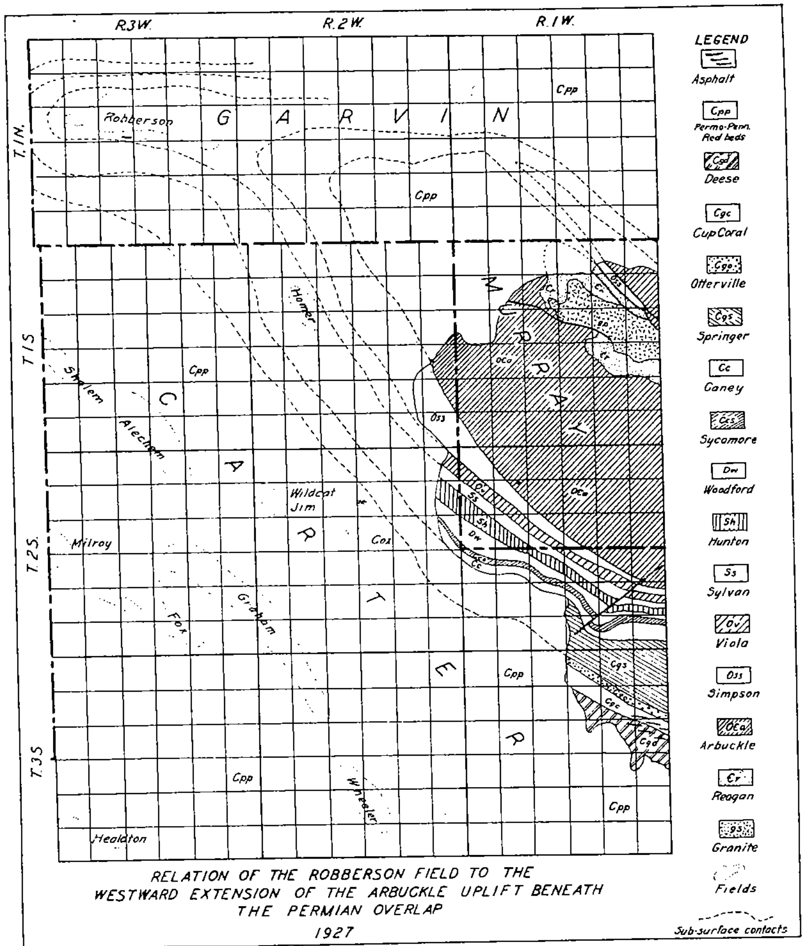


Figure 23.—Westward extension of the Arbuckle Mountains.

grains of quartz are angular. The smaller grains of quartz are frosted and well rounded, while the feldspars are only slightly rounded. The condition of the particles indicates short transportation and rapid erosion from a nearby land mass. The frosted grains are from the eroded Simpson formation. These sands are found from the top far down the flanks on all sides of the buried hills but they do not seem to extend as producing sands beyond the immediate vicinity of these hills. They are productive of much gas and can be correlated over the whole field though not equivalent in age, as those at the bottom are older than those at the top of the hills. The upper mem-

bers of this sand series which are found on the flanks of the buried hills are probably equivalent in age to the gas sands occurring on top of these hills. The Homaokla Hervey No. 1 SW.¼ NE.¼ NW.¼ NW.¼ sec. 14, T. 1 N., R. 3 W., produced 20,000,000 feet of gas and 60 barrels of oil initial yield. This well is down the north slope of the buried hills. None of the other wells producing oil from these sands has sufficient gas to make them flow longer than a few days. Two members of the Newberry sands, near the top of the buried hills, have a constant interval over local areas but vary greatly over different parts of the field. The discovery well produced from the upper sand, but many later wells found this sand barren and were drilled to the lower horizon.

In other parts of the field only one of these sands is found to be productive. It is considered to be the lower member as this sand is more persistent and is a better producer than the upper one. Below these two sands numerous shows of oil and gas are found, but only one commercial producer, Hart Ringer No. 4, SE. cor. SW.¼ SW.¼ sec. 11, has been completed. Deeper drilling in other parts of the field have found not further encouragement.

ORDOVICIAN

The big pay horizon in the buried hills ranges from 4 to 402 feet below the base of the Pontotoc. The biggest wells have found the oil only a short depth in the hills as Nelson Brothers' Jones No. 5 was drilled 22 feet into the limestone, Humble's Powell No. 1 four feet in, and Texas-Pacific's Pearce No. 2, ten feet in. These wells are located in sections 13 and 14. The depth of production varies, due to the folded and faulted conditions existing in the buried hills and to the amount of the Viola limestone eroded. Samples indicate that the production all comes from one horizon below the Viola limestone.

An interesting fact is that offsets to the biggest wells in the field did not make more than 150 barrels per day initial production, although in some cases the offset was producing from the same or greater depths before the "gusher" well came in. This shows that the oil has accumulated in pockets and lenses of the pay horizon, which is probably due to faulting and to the degree of cementation of the sand.

STRUCTURE

SURFACE

The surface structure is very difficult to work because of unreliable exposures. Even when good exposures are found they are very difficult of interpretation due to the slumping and probable faulting to whch they have been subjected, both from actual movement and from differential settling of the Permian beds on all sides of the Robberson buried hills. Several things, however, are quite evident from the outcrops: there is a definite south dip in sections 23 and 24; also a southwest dip in section 16. A west dip may possibly be recognized in section 17.

Pierce Larkin in working over the Robberson area recognized what he thought to be an anticline.

SUBSURFACE

Permian

Any interpretation of the subsurface conditions in the Permian formations is extremely difficult due to the lenticular character of the beds and to the great unconformity between the Permian and the older sediments. However, fairly good results may be obtained by contouring on the lime cap above the Newberry pay horizon.

A contour map on the Permian pay zone, which is not included in this report, shows a great many irregularities in sections 13, 14, and 16. This may be due in part to local faulting. Also, the domes or highs found in the Permian are in every case the direct reflection of corresponding highs in the buried hills, and therefore, the contour map in Figure 22 may be taken as the same for the Permian, except that the relief of the Permian is not so pronounced.

Pontotoc

The same difficulty that one has in contouring the Permian is encountered when he tries to contour the Newberry sands, as they are definitely known to be very lenticular.

Ordovician

The contours in Figure 22 do not represent the attitude of the strata in the older formations, but they do represent the topography of these hills as they were gradually buried by the advancing seas before the Permian and Pennsylvanian deposition The contours show an irregular range of hills striking to the west and rapidly dying out in that direction, as the last notable peak is to be found in section 16. Samples from various wells penetrating the older sediments show that the dips in the formations are quite high, in some cases above 45°, especially on the northern flank.

ORIGIN OF STRUCTURE

The Robberson buried hills are composed of sedimentary rocks and are the northwest continuation of the Arbuckle Mountains. The older sediments and igneous rocks composing the Arbuckle Mountians plunge under the Permian and Pontotoc in the eastern part of T. 1 S., R. 2 W., the Permian sediments overlying the Robberson hills have, since their deposition, been subjected to all later movements that may have occurred in the Arbuckle Mountains. Also these sediments have undergone a certain amount of differential settling after deposition which allowed them to settle on all sides of the buried hills. Differential settling accompanied by possible movements in the

Arbuckle Mountains will account for the 200 feet of closure which is found in the Permian and Pontotoc pay horizons.

The structure permitting the accumulation of oil in the Robberson field differs from most of the other structures of southern Oklahoma, in that the latter are buried truncated folds parallel to the main Arbuckle uplift. These truncated folds are not continuous, but have a tendency to be en echelon with each other. They may in some cases have a structure similar to that of the Criner Hills which are a series of fault blocks, while on the other hand the Robberson Hills are a direct continuation of the Arbuckle Mountains beneath the Permian and Pontotoc overlap.

The production of the Robberson field comes from the Permian, Pennsylvanian and Ordovician.

RELATION OF STRUCTURE TO PRODUCTION

Oil and gas occur on the northern flank of the pool, but not on the southern and southwestern flanks, except in very few isolated places, and then only in small amounts. The producing sand is continuous over the south side in spite of this segregation of the production on the northern flank.

The production on the north sides seems to be limited by the pinching out of the sands, as many dry holes in the area record no "pay" sand at the regular horizon. These sands are, no doubt, very lenticular in character, as indicated by the logs and records of producing wells, because a dry hole is often offset by a 1,000 barrel gusher. The gas wells are mostly in the Permian and Pontotoc, though many of the wells in the Ordovician produce a great amount of gas with high pressure. This is probably the cause of the emulsion of oil and connate water which was found so hard to break when the wells were brought in from below the Viola limestone, and which caused a great loss of oil. The gas pay is also very lenticular in character. It occurs on the summit and well down on all flanks of the Robberson hills. The gas wells are located over the peaks of the Ordovician in sections 13 and 14, as well as in sections 15 and 16. The saddle between sections 14 and 15 is productive of oil.

All the peaks of the buried hills shown in Figure 19 are productive of oil and gas. The highest peak in sections 13 and 14, however, has had the largest wells in the older sediments.

ORIGIN OF OIL AND GAS

Chemical analysis of the oil in the Pontotoc as compared with the analysis of the oil in the Ordovician shows both oils to be identical. This would preclude the possibility of the oil in the Pontotoc and the Mauldin beds from having a different source than that found in the Ordovician.

The following discussion in which three theories will be presented is made with the supposition that the oil is derived from a single source.

The first theory is that the oil and gas may have had their origin in the Permian sediments surrounding the buried hills. In the Carter-Knox field in T. 3 N., R. 5 W., about ten miles to the northwest of Robberson, the oil may have originated in a gray shale intercalated in the red beds which occurs at a depth of about 1,000 feet. The Permian origin for this oil is doubted by several geologists, as they recognize a fault in the field which may have allowed the oil to migrate upwards from below. However, there are several facts which militate against the acceptance of this theory in the Robberson field. In Figure 21 the accumulation of the oil and gas is shown to be on only one side of the pool, namely the north flank. This segregation of the oil and gas on the north flank of the pool is not due to the pay sand occurring only there, since the same porous sand may be found on the south flank and at the same relative horizon. This accumulation would lead one to believe that the oil was derived from some place to the north of the pool. If the oil were derived from the Permian it should occur on all flanks of the buried hills.

Other facts which do not argue in favor of the oil and gas coming from the Permian are as follows: In the Mauldin beds the sands are more or less connected and they have produced most of the gas from the field. In a few places a very heavy asphaltic oil is found in these sands. In the Newberry sands a general connection is also found. Most of the oil produced from this series of sands, is a lighter gravity oil and is associated with considerable gas. These sands are notably free of water, as when a well producing from them is abandoned water does not flow in to take the place of oil. In the Ordovician all the production was of the gusher type and of very short duration. This oil was under hydrostatic head and had a very high gas pressure. There seemed to be very little connection between the producing wells, as gushers were frequently offset by wells producing only 150 barrels per day. All of these wells were drowned out by connate water.

In the light of these facts and supposing the oil and gas to have migrated up the north flank of the pool through the course Pontotoc sands a fault must be postulated in order to allow accumulation in the Ordovician. It seems highly improbable that the oil and gas should have migrated downwards along these fault planes into the Simpson, and against the connate water which it contains, and after arriving there, to have accumulated in lenses and pockets which were subsequently sealed off sufficiently to prevent further connections. Furthermore, this migration is contrary to the generally accepted theory regarding an interchange of oil and water, as we have a sand in the Pontotoc and in the Simpson, yet the Pontotoc sands are

free of water. It will also be noted that the gravity of the oil and the relative amount of the gas increases the farther it is removed from the Ordovician, which would not indicate a migration from the Permian into the Ordovician. This will be explained in the third hypothesis.

A second hypothesis, and one which seems tenable for the accumulation of the oil in this pool, is that the oil originated in the Glenn formation. It is known that the Glenn formation is productive of oil in southern Oklahoma, also that where it crops out asphalt seeps are frequently found. From the facts presented on the areal map (Fig. 23) it seems reasonable to suppose that the Glenn formation found on the south and west sides of the pool swings around to the north and is present either as such or its equivalents. These beds are probably dipping at an angle greater than 35° to the north. In Figure 24a, a north-south profile is drawn through the sections shown. The base of the Pontotoc is accurate south of section 11 while to the north of this section the base of the Pontotoc is generalized. There is a depression between sections 34, 35 and sections 14 and 15, T. 1 N., R. 3 W. In the intervening sections 20-28 the base of the red beds is found at a much greater depth than those sections immediately to the north and to the south. This depression would prevent any migration of oil from the south; and production from the Magnolia well in sec. 31, T. 1 N., R. 3 W., also proves that there is a second high, although probably very small, immediately to the southwest of Robberson. Wells drilled in sections 20-28 are all dry. From this evidence it seems probable that the oil may have migrated out of the Glenn formation and up the northern flank of the buried hills through the Pontotoc. This migration would account for the peculiar accumulation of oil and gas on the northern flanks of the buried hills.

The conditions which this hypothesis does not seem to satisfy are the same as those for the Permian excepting the fact that the position of the Glenn as shown would give an accumulation on the north flank if the Glenn was the source of the oil.

The last theory and the one which seems to be the most applicable is illustrated in Figure 24b. This figure is drawn the same as Figure 24a only more emphasis is laid upon the Ordovician as the source of the oil and gas. The oil is shown as having migrated along the fault planes through the Viola limestone from the Simpson formation, finding its way out on the north flank of Robberson, and then back up that slope thus giving the present accumulation.

The general tectonics of the nearby Arbuckle Mountains, the abnormal thickness of limestone recorded in several of the deep wells, together with the fact that the section below the Viola limestone corresponds with the Simpson section in the rest of the state, show that the Robberson uplift represents an asymmetrical fold with the steep dip on the north side, as the forces which produced the

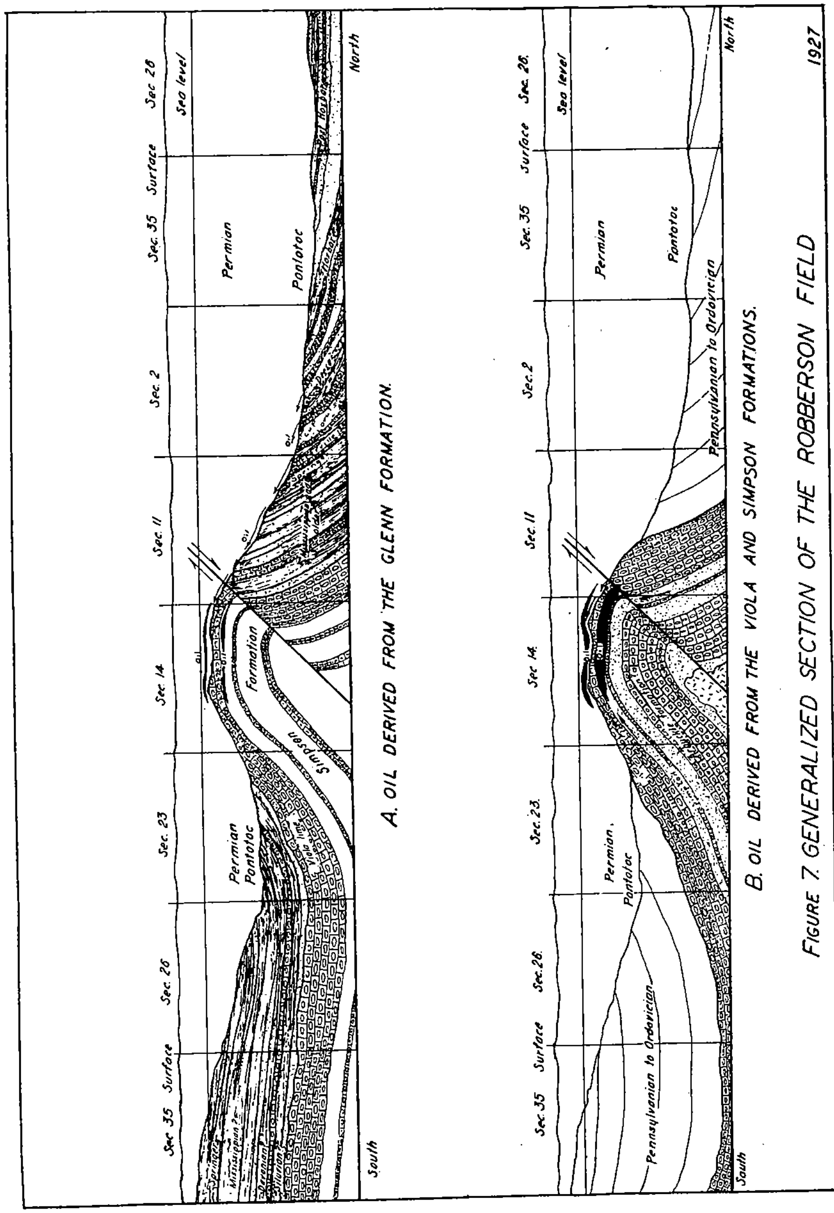


Figure 24.—Generalized cross-section of the Robberson field.

uplift were probably directed from the southwest. It will be noted that there are a number of faults and parallel folds to the south and southwest, while none of these occur in such magnitude on the north side of the Arbuckle Mountains. The Robberson fold has probably been faulted several times, though the vertical displacement is not great. The faults generally have a northwest-southeast strike with the downthrow on the north side. This fault zone has been generalized into one fault in the figure above mentioned. There can be little doubt that certain parts of the Simpson in the Arbuckle Mountains contain oil as there are many asphalt seeps along the outcrop of this formation. It is to be understood that the oil is not indigenous to the Simpson sands, but to the Ordovician limestones; and it is thought that an accumulation at Robberson occurred subsequent to the uplift. Erosion progressed until most of the Viola limestone was removed over the tops of the structure and near the close of this erosional period there probably was a large asphalt seep situated at Robberson. This seep was sealed in by the last advancing seas of the Pennsylvanian which deposited the Pontotoc, and possibly a part of the Mauldin sands. Permian deposition then commenced which laid down the rest of the Mauldin beds and the Garvin beds. Any later Permian beds which may have been deposited over this area have subsequently been removed. This asphalt seep at Robberson continued to disseminate gas and oil into these younger beds, resulting in a heavier oil in these younger beds because the more volatile constituents escaped as a gas.

In spite of this theory, the oil may have had a dual origin or it may have all been derived from the Glenn formation.

PRODUCTION

OIL

There are two classes of producing wells in the field. One is from the Permo-Pennsylvanian, which had an average initial production of 50 barrels per day (in some exceptional cases this initial production ran as high as 250 barrels). The other is from the Ordovician, which had a maximum initial production of 8,000 barrels per day.

The oil produced in both cases is a black mixed-base crude, varying in gravity from 25° to 33° Baumé, the average being 28°. The lightest oil is found in the Simpson sands below the Viola limestone. The gravity becomes progressively heavier the farther it has travelled into Permian sediments. Due to the lack of proper facilities for conserving the lighter constituents of the oil, most of it is sold as low gravity crude.

An average analysis of the oil shows the following fractions and temperature ranges of distillation:

Gasoline and Naptha below 302° F; 15.5 to 21.4 per cent.
Gasoline at 302° F; 11.1 to 15.8 per cent.
Kerosene at 302° F; 21 to 28 per cent.
Residuum at 572° F; 67.3 to 67.9 per cent.

The oil from the Permo-Pennsylvanian is notably free from water.

Many of the sands have been entirely penetrated and no water encountered. The oil from the producing horizon of the buried peaks shows water and emulsion which has caused a great loss of oil as it is extremely difficult to break, and since several of the wells have had as much as 25 per cent of this water and oil emulsion, the waste in getting it into pipeline condition has been quite large. The water may be separated by treating with chemicals, but the most efficient means is to treat this emulsion in centrifugal separators.

There has been a total of 342 wells drilled in the field up to the present time and of this number 221 produced oil and gas, and 52 were gas wells. The remaining 69 were dry or were abandoned.

GAS

Gas was the first commercial product of the field, yet no effort has been made to develop the supply. The gas from the first few wells drilled was used for fuel in drilling later wells, and it was not until January, 1923, that an adequate pipeline was connected with the field. A great many of the gas wells in the field were the result of plugging back from a failure to find oil at lower depths.

The average initial gas production was from 15,000,000 cubic feet to 35,000,000 cubic feet per day. These wells were of fairly long life some of them were producing 8,000,000 cubic feet per day when two years old. The rock pressure varied from 275 to 600 pounds, the average being 350 pounds, and the gas was usually free from water and was low in gasoline content. Samples taken from various wells showed from 0.6 to 0.8 of a gallon of gasoline per 1,000 cubic feet of gas. This was too low to be of commercial value, and very little casing-head gas was made by the oil wells. No effort has been made to utilize this supply.

DECLINE CURVES

The production curves of the wells in the Permian and Pontotoc as compared to those of the Ordovician differ radically in their form. For example, the wells producing from the Newberry sands show, in general, a rapid but very regular decline with very little flattening until the wells are more than a year old. These wells are generally much longer lived than those in the Ordovician, due to the coarseness and porosity of the sands and to the absence of water even after the available oil has been extracted.

The wells drilled into the older sediments have a very large initial production with a sharp, early decline followed by a flattening of the curve after seven months. This type of curve generally indicated water pressure. All of the large wells are on the apex of the buried peaks in sections 13 and 14. They are short-lived, flowing from two to three weeks and declining rapidly as the gas pressure decreased. For example, Humble's G. Powell No. 5 came in in May with an initial production of 8,000 barrels per day, and one month later it was pumping 50 barrels per day.

The decline curves showing the volume and rock pressure of a gas well when allowed to produce naturally give almost a straight line with some fluctuations. However, if a gas well is "pulled" the volume and pressure becomes abnormally low, but will re-establish itself after allowing the well to be shut in for several weeks.

In a curve showing the average daily production of oil per month, a number of high points can be shown which in every case are due to the bringing in of a gusher from the Ordovician, since these gushers had a high initial yield. Since June, 1923, there has been a steady decline in this curve. Its high point was 87 barrels per day per month, while at present it is little better than 12 barrels.

METHODS OF DEVELOPMENT

WELL SPACING

The early wells in the field were all drilled as line locations, 150 feet being the usual distance, but as the field progressed and many small tracts were developed, wells were spaced in an irregular manner according to the individual idea of the operator. The closest spacing is around gusher wells, where as many as four wells were drilled on 10 acres. However, in the Permo-Pennsylvanian coarse sand, the usual method was one well to 10 acres, and this spacing was found to be sufficiently close to drain the oil from the coarse sands. Wells on the buried hills were drilled much closer as it was found that the horizontal distance of 100 feet would mean the difference between a small well and a gusher.

DRILLING SYSTEMS

Rotary tools were used exclusively to drill through the upper Permian beds. The common practice was to set a string of 8¼-inch casing on top of what was thought to be a producing horizon. The hole was then finished with either standard tools or a Star drilling rig, setting a liner from the bottom of the 8¼-inch casing to the top of the producing horizon.

All gas wells were drilled in with rotary tools. After cementing the 8¼-inch casing, the sand was penetrated and as the mud was thinned the wells usually "cleaned" themselves. Only one string of casing was necessary in drilling the average well. When deeper tests were made, a string of 6⅝-inch casing was carried down the hole to shut off water horizons passed through.

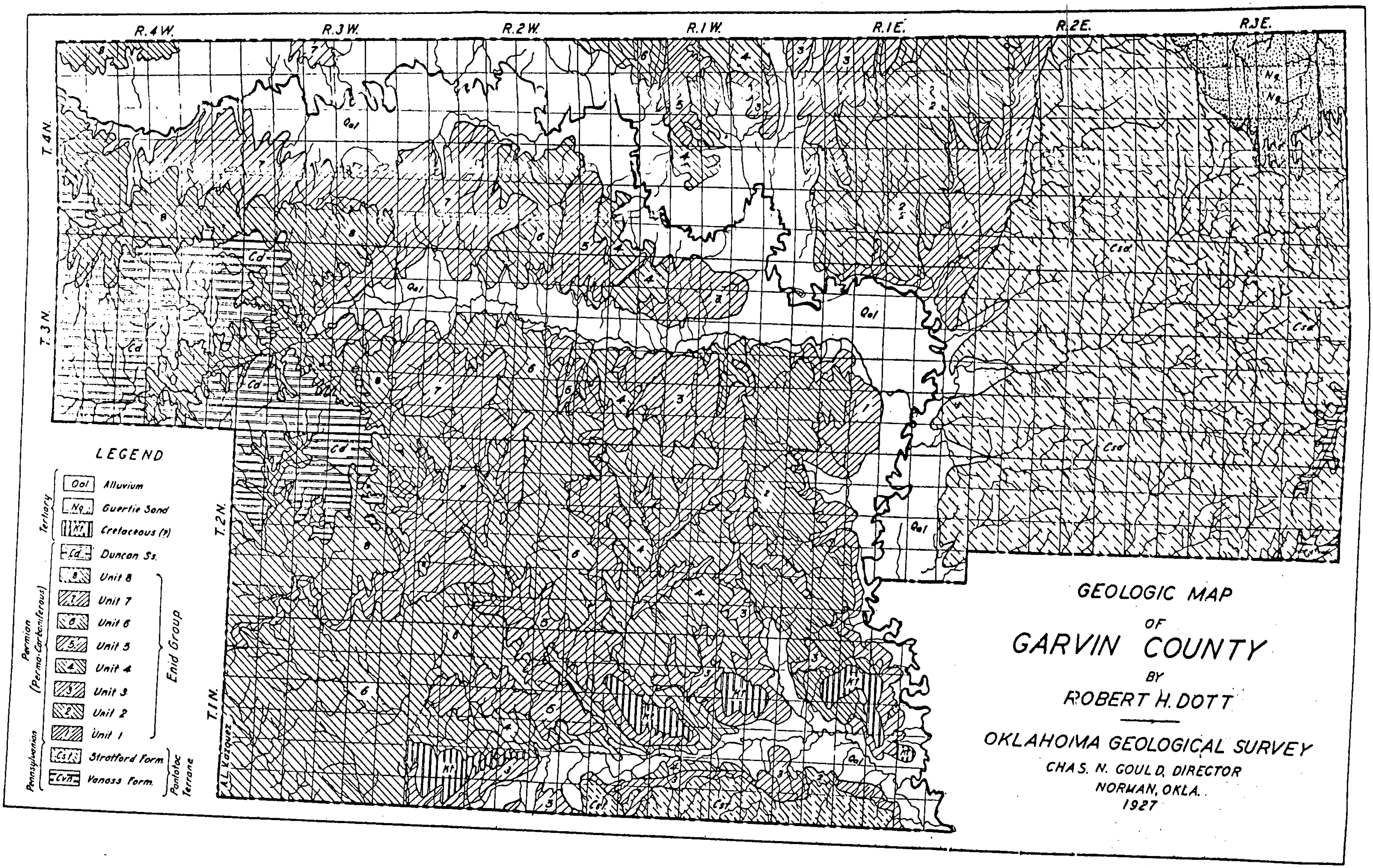
PIPELINE FACILITIES

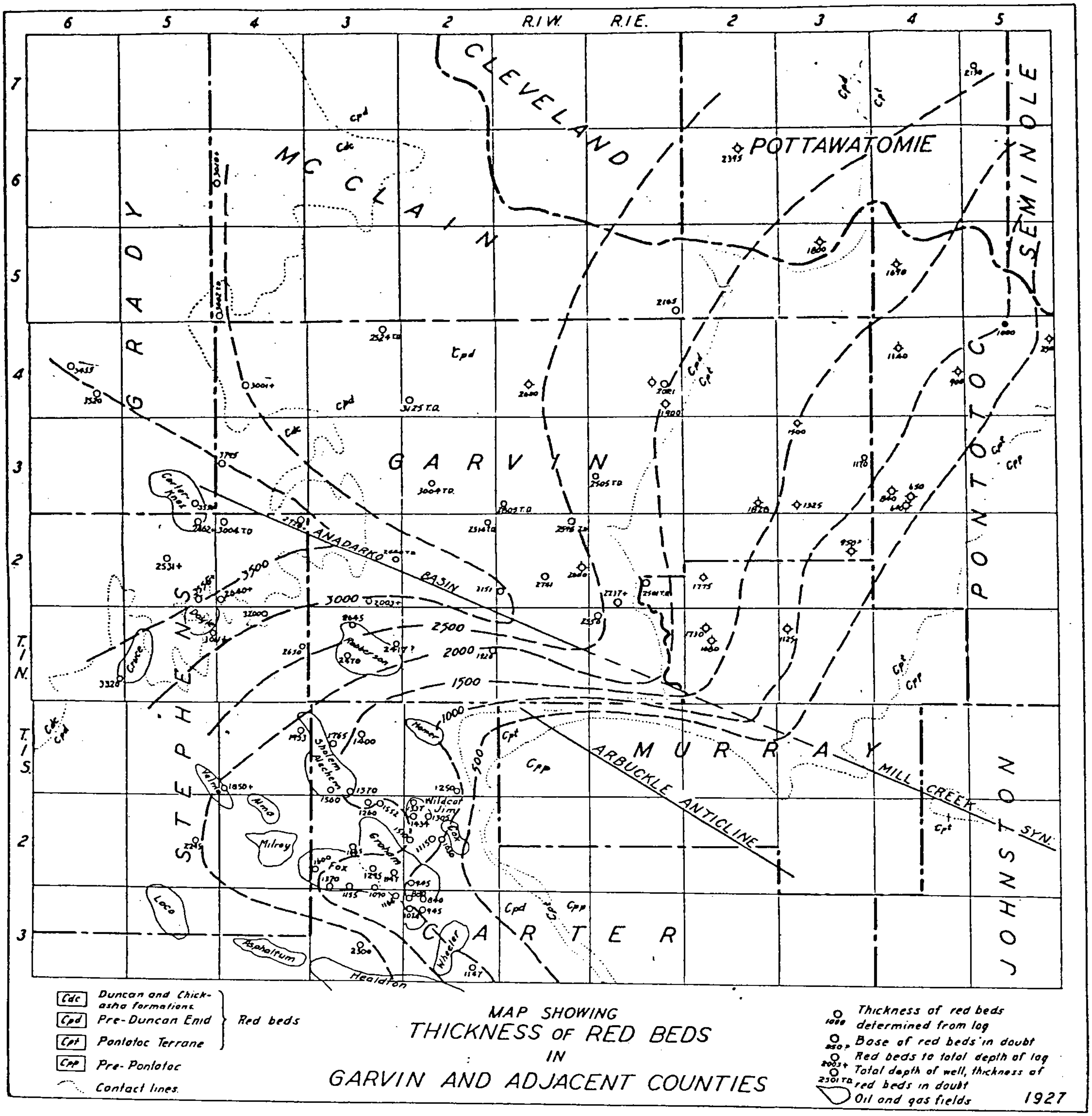
Two pipelines run oil from the Robberson pool. The Magnolia Petroleum Company has a 6-inch line to Healdton with a capacity of 6,000 barrels per day. It began operation January 1, 1922, and has carried most of the production from the field. The Texas-Pacific Coal and Oil Company have a 4-inch line to their refinery at Wynnewood which has a capacity of 5,000 barrels. The independent operators were prorated on the Texas-Pacific Coal and Oil Company line. Aside from the stock tanks on the leases the only storage is two 55,000-barrel tanks used by the Texas-Pacific Coal and Oil Company in connection with their pipeline.

The Lone Star Gas Company is the only purchaser of natural gas. This company has a 12-inch delivery line connecting with a 16-inch trunk line at Dixie, Oklahoma. The pumping plant has six 160 hp. engines with a total daily capacity of 15,000,000 cubic feet. This plant started operation January 4th, 1923 and the amount of gas taken per day varied with the needs of the purchaser, the output decreasing in summer and increasing in winter. In 1923 the producer was paid 6c per 1,000 cubic feet and the amount taken was prorated among all the operators.

CONCLUSION

As a producing field the Robberson pool is fast becoming history and in a few more years its production will be very small. Up to the present date the gross production of the field is 5,376,150 barrels, which is an average yield per acre of 1,680 barrels. Probably the final yield will not be much more than 2,000 barrels per acre when the field is abandoned. There can be no further hope of another producing horizon in the area by drilling deeper, as the Arbuckle limestone and the Reagan sandstone rest unconformably upon the granite porphyry. However, the Magnolia's Burr No. 1, sec. 31, T. 1 N., R. 3 W., may open up a new productive area in the upper Glenn formation immediately south of the Robberson field.


R. 4 W.
R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
R. 2 E.
R. 3 E.
T. 4 N.
T. 3 N.
T. 2 N.
T. 1 N.
LEGEND
Qal Alluvium
Ng Guertie Sand
Kt Cretaceous (?)
Cd Duncan Ss.
Unit 8
Unit 7
Unit 6
Unit 5
Unit 4
Unit 3
Unit 2
Unit 1
Csf Stratford Form.
Cvn Vanoss Form.
Tertiary
Permian (Permo-Carboniferous)
Pennsylvanian
Enid Group
Pontotoc Terrane
A. L. Vazquez
GEOLOGIC MAP
OF
GARVIN COUNTY
BY
ROBERT H. DOTT
OKLAHOMA GEOLOGICAL SURVEY
CHAS. N. GOULD, DIRECTOR
NORMAN, OKLA.
1927



MAP SHOWING
THICKNESS OF RED BEDS
IN
GARVIN AND ADJACENT COUNTIES
1927