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OIL AND GAS IN OKLAHOMA

OIL AND GAS GEOLOGY OF KAY, GRANT, GARFIELD AND NOBLE COUNTIES

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FOREWORD

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

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

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

The four counties embraced in this report, Kay, Grant, Garfield and Noble, are located in the northern part of Oklahoma, Kay and Grant bordering on Kansas. Two of Oklahoma's major oil fields, Garber and Tonkawa are located in this region, and in addition there are more than a score of oil and gas fields.

Mr. Glenn C. Clark, one of the coauthors of this paper, who is chief geologist of the Marland Oil Company, had had opportunity through many years of study to become thoroughly acquainted with both the surface and subsurface geology of the area, and also with production of the various fields. The report in its present form was writtn by Mr. C. L. Cooper of the Oklahoma Geological Survey from material furnished by Mr. Clark and others. The maps have been drawn chiefly by Mr. Cooper and Mr. A. L. Vasquez.

March, 1927

CHAS. N. GOULD
Director

OIL AND GAS IN OKLAHOMA

KAY, GRANT, GARFIELD AND NOBLE COUNTIES

ACKNOWLEDGMENTS

The material for the compilation of this report was obtained largely from the Geological Department of the Marland Refining Co. The data on the Tonkawa and Thomas fields was used as it is found in the Bulletin of the American Association of Petroleum Geologists. For these articles, and for much additional help and criticism of the report in manuscript form, the authors are indebted to F. L. Aurin, S. K. Clark, and J. I. Daniels of the Marland Company.

Much of the early history of the fields was obtained from Ira Reinhart's report on the northern Oklahoma oil fields. The American Association of Petroleum Geologists has kindly loaned the cuts of the illustrations for the Tonkawa and Thomas fields.

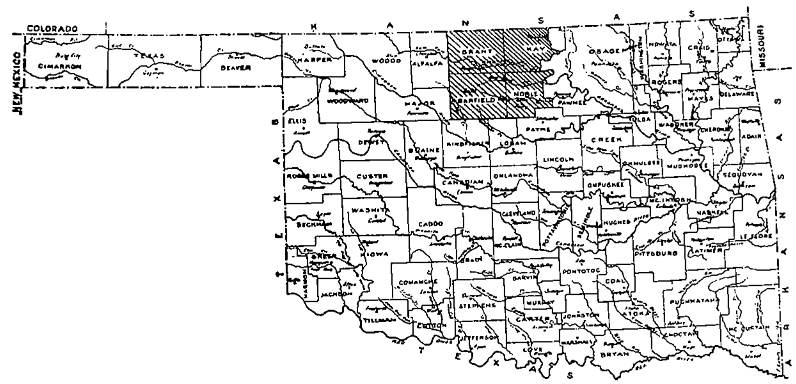


Figure 1—Index map showing area covered by this report.

STRATIGRAPHY

SURFACE FORMATIONS

The rocks exposed on the surface in the four counties under discussion include formations of late Pennsylvanian and lower Permian age, the oldest being exposed in east-central Kay County in T. 27 N., R. 5 E. The Pennsylvanian formations consist of numerous beds of drab colored limestones interbedded with drab to red colored shales. The limestones range from a few inches to 15 feet or more in thickness. The Neva limestone, believed by Beede to mark the Pennsylvanian-Permian contact, seems to define to a certain extent the change of color of the rocks other than the limestones; the shales and sandstones above the Neva are predominately red while those below are the typical drab color of marine sediments. The limestones without exception thin out to the south and are replaced by red shales and sandstones.

The following table shows a generalized section of the Pennsylvanian rocks in eastern Osage and western Kay counties:

Pennsylvanian section in T. 22 N., Rs. 2 W.-5 E.

		Feet
	Limestone, Neva	
	Sandstones, shales, and some limestones, alternating red and gray	65
	Shales, red and gray, Red Eagle	19
	Limestone	3
	Sale, mostly red	9
	Limestone, Cushing	7
Foraker	Shale, mostly red	37
Foraker	Limestone	3
Foraker	Shale, gray	7
Foraker	Limestone	5
Foraker	Shale, gray, with red streaks	10
Foraker	Limestone	7
Foraker	Shale, gray, with read streaks	12
Foraker	Sandstone, non-red	13
Foraker	Shale, gray, with red streaks	9
Foraker	Limestone	5
Foraker	Shale, gray	8
	Limestone	4
	Shale, gray	164
	Concealed	
		450

The Permian section is made up of a few thin non-red limestones, red and non-red shales and sandstones near the base with an increasing thickness of red shales and sandstones as one goes higher in the section. In this area are found most of the non-red Permian rocks of the State, the color change line[1] crossing the Pennsylvanian Permian contact in T. 18 N., R. 4 E.

The Permian section as exposed at the surface is shown in the following table:

1. Aurin, F. L. Officer. H. G., and Gould, Chas. N., The subdivisions of the Enid formation: Bull. Am. Assoc. Pet. Geol., Vol. X, No. 8, 1926.

Permian section in T. 24 N., Rs. 3 W.-2 E.

	Feet
Shales, red with some sandstones to top	210
Shales, purple	55
Shales, red	42
Shales, mostly non-red, some sandstones and limestones	252
Shales, red and non-red, sandstones, and gypsum alternated	267
Gypsum	5
Shales and sandstones, red and non-red, some gypsum	130
Gypsum	8
Shales, mostly red	37
Limestone, Herington, shale partings near top	26
Shales, red	50
Limestone, Winfield, thin shale parting in middle	13
Shales, red, some sandstones and thin limestones at base	153
Limestone, Fort Riley	10
Shales, mostly red, some sandstones	101
Limestone, Wreford	16
Shales, red and non-red, some sandstone	68
Limestone, Crouse	2
Shales, red and non-red, some sandstone	67
Limestone, Cottonwood	6
Sandstone and shales, non-red	75
Limestone, Neva, alternating limestone and shale	34
	1,627

NEVA LIMESTONE

The lowest formation exposed in this area is the Neva limestone. It is found outcropping at the surface in east-central Kay County in sec. 27, T. 27 N., R. 5 E. The Neva is composed of four thin beds of limestone separated by beds of gray shale. The formation thins to the south, but in T. 26 N., R. 5 E., has an aggregate thickness of 35 feet. The following section by Bowen[2] shows the detailed character of the formation:

Section of Neva limestone near Burbank

	Feet
Limestone, gray, somewhat cherty, soluble; chert commonly lying loose on the surface	2
Shale	6+
Limestone, containing large, gray, nodules of chert; both chert and limestone full of large Fusilina, chert nodules white on freshly broken surface; weathers brown with a sandy appearance	2
Shale	8
Limestone, gray; weathers white; contains no fossils or chert; weathers into large, thin, sharp-edged slabs; forms prominent rim	4
Shale	12
Limestone, dense, non-crystalline; has straw-yellow color or streaked with maroon; contains pelecypods; rarely well exposed	2½
	36½

2. Bowen, C. F., Oil and gas resources of Osage Reservation, Oklahoma: U. S. Geol. Survey, Bull. 686, p. 140, 1922.

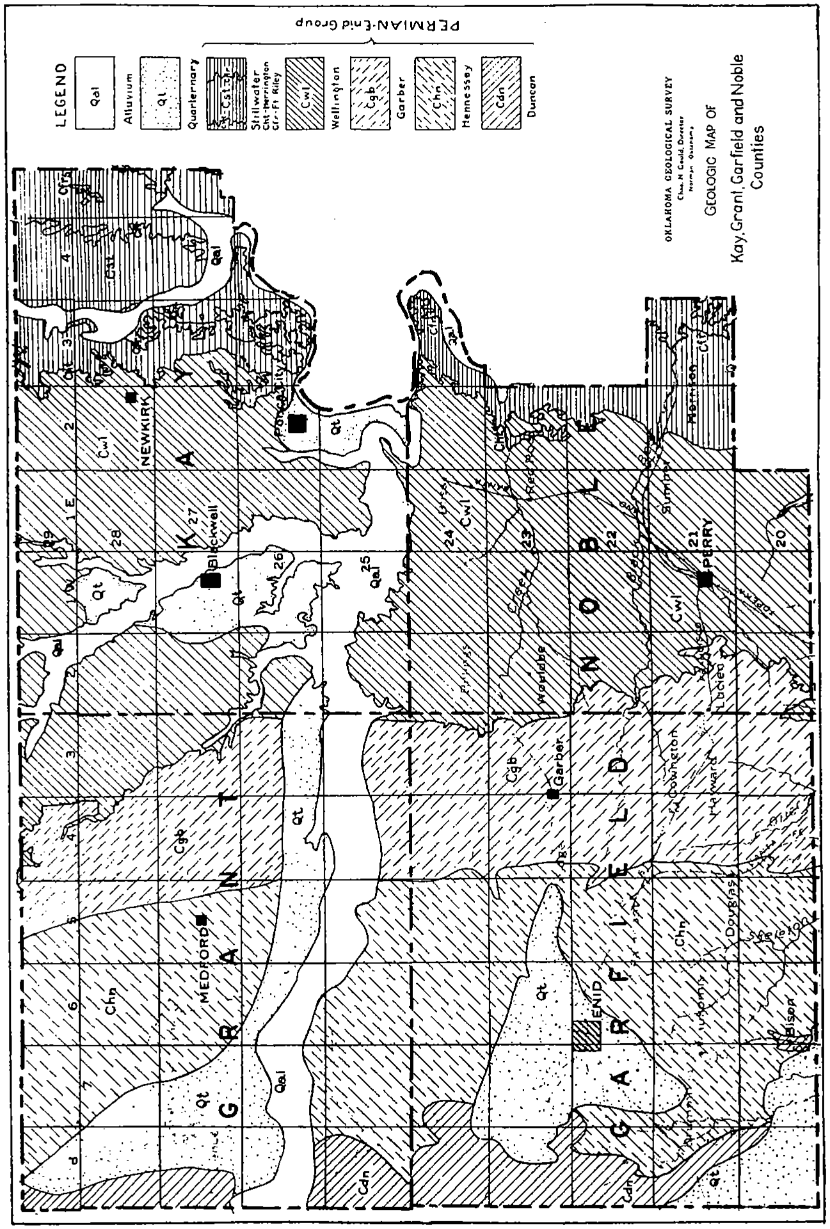


Figure 2—Geologic map of Kay, Grant, Garfield and Noble Counties.

COTTONWOOD LIMESTONE

The Cottonwood limestone is about 6 feet thick in this area. It is a white to light gray hard, crystalline limestone, slightly oolitic and fossiliferous in places. The only exposure of the Cottonwood in this area is found along Beaver Creek in Tps. 27 and 28 N., R. 5 E.

The following section, by Heald[3], was measured in Osage County.

Section of Cottonwood limestone in SW.¼ sec. 21, T. 29 N., R. 6 E.

	Ft.	In.
Limestone, massive, bluish white on weathered surface, light gray to buff on fresh surface; surface uneven and full of round holes as much as 2 in. in diameter, but it is not as rough as the Neva; occasional rough places have dark surfaces; no chert	2±	
Shale, thin; and oolitic limestone	11	0
Limestone conglomerate, blue, gray to yellowish; made up of rolled pebbles of limestone, shell fragments, and some little hematite pebbles; degree of cementation varies; a good deal of crystalline calcite; many fossils; coiled shells **(Schi ostoma)** and fluted, long-nosed brachiopods **(Meekella)** most characteristic		6
Shale, olive-drab, clay		20
Limestone conglomerate as above, except that it contains more pebbles and less lime; fossiliferous, **(Myalina)** productids; cross-bedded largest pebbles seen about half an inch in diameter	2	0
Shale or marl, pink, greenish gray, and white, bedding irregular; beds form overlapping lenses; contact with overlying conglomerate very irregular	2	6
	20±	

CROUSE LIMESTONE

The Crouse limestone[4] is a very thin limestone about two feet thick in this area, lying 100± feet above the Cottonwood limestone. The Crouse outcrops in east-central Kay County in T. 28 N., R. 5 E. It is commonly a light-gray thin-bedded limestone, but in places is massive throughout its entire thickness. The limestone is very porous and in places very fossiliferous. The formation has not been traced farther south than sec. 5, T. 27 N., R. 5 E. At this place the interval between the Crouse and the underlying Cottonwood is 64 feet.

WREFORD LIMESTONE

The Wreford limestone is exposed in northeastern Kay County in Tps. 27-29 N., R. 5 E. and generally consists of two beds of limestone separated by a shale of variable thickness. The lower limestone is a bedded, buff to gray limestone averaging 8 feet thick and forms

3. Heald, K. C., Oil and gas geology of the Foraker Quadrangle, Osage County, U. S. Geol. Survey, Bull. 641-B, p. 23, 1917.
4. Heald, K. C., The oil & gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey, Bull. 641-B, pp. 21-22, 1922.

broad sloping terraces terminated on the east by a high scarp. The lower bed, averaging two feet thick, is a yellowish fossiliferous limestone. The interval between the Crouse and the Wreford is 86 feet. The Wreford is the basal member of the Chase group of Kansas. The following section[5] was measured in Osage County.

Section of Wreford Limestone, Osage County, Oklahoma.

	Feet
Limestone, blackish gray on weathered surface, light buff to brownish gray on fresh surface; in several slabby beds 2 to 6 inches thick; top bed is massive, 12 to 16 inches thick, hard and dense; lower beds break into slabby, lenticular pieces. Fossiliferous; considerably limonitized; has many echinoid spines; is in places full of smooth cylindrical holes half an inch to 3 inches in diameter. Above this is a mass of shale and limestone	4
Limestone, buff, hard, dense, massive; full of chert; yellowish brown on weathered surface, blue-gray on fresh surface. About 25 per cent of the rock is chert, in irregular nodules and layers, lens-shaped concretions roughly parallel to bedding most common; chert is fossiliferous	3
Shale, limy, yellow-gray to green-gray; looks sandy but no grains distinguishable; bedding regular; fossiliferous	2
Limestone, light buff on both weathered and fresh surfaces, dense, hard, compact; full of fossils, which are locally replaced by glassy or milk-white calcite; in two beds with a 1-inch shale parting; the many crystalline fossils give the rock a spotted appearance	3
	12

FORT RILEY LIMESTONE

Between the Fort Riley limestone and the Wreford there occurs a series of red shales and sandstones having a total thickness of 100 feet in sec. 5, T. 27 N., R. 5 E. To the north thin limestones appear, the red sands disappear and the section changes to one of drab limestones and shales. The Fort Riley is a massive buff limestone averaging 10 feet thick, exposed in a broad band of irregular outcrops in Tps. 25-29 N., R. 4 E., and crossing into T. 25 N., R. 3 E., in section 24. An exposure of this formation is also found in the large bend of the Arkansas River northeast of Bressie.

WINFIELD LIMESTONE

Between the Fort Riley and the Winfield there is a thickness of 150-160 feet of red shales with some non-red shales, sandstones and a few thin limestones in the lower half of the interval, corresponding to the Doyle shales of the upper Chase group of Kansas. These non-red beds increase to the north and decrease to the south in the

5. Heald, K. C. The oil and gas geology of the Foraker Quadrangle, Osage County, Oklahoma: U. S. Geol. Survey, Bull. 641-B, p. 22, 1917.

section. The main outcrop of the Winfield is found in eastern Kay and Noble counties, southeast of Ponca City and east of Newkirk. Three outliers occur in the eastern part of T. 27 N., R. 3 E., just east of Mervine. The Winfield in this area varies from 9 feet in sec. 18, T. 22 N., R. 3 E., to 18 feet at the Kansas line, and continues to thicken to the north in Kansas. It cannot be definitely recognized any considerable distance south of the exposure in sec. 18, T. 22 N., R. 3 E. where the limestone is separated into two beds by a parting of red shale 3 feet thick.

HERINGTON LIMESTONE

The Herington limestone is separated from the Winfield by an interval of 50-60 feet of beds, which, like the beds described above, consist of drab to gray limestones and shales at the Kansas line, changing to red shales and sandstones to the south. These shales are the equivalent of the Enterprise shale in Kansas. The Herington is composed of one to three members of light buff-colored limestone which thins to the south, where there is found a massive sandstone just below the limestone. The Herington has an aggregate thickness of 26 feet near the Kansas line. The outcrop of this limestone closely parallels that of the underlying Winfield limestone in east-central Kay and Noble counties, and can be definitely traced as far south as sec. 14, T. 22 N., R. 2 E.

The rocks which lie above the Herington are made up almost entirely of typical red beds formations as shown in the section on p. 17. These beds occur in an alternating series of red sandstones and shales, with numerous gypsum beds, interspersed throughout the section. The series as a whole, from the base of the Neva up, are included in the Stillwater, Wellington and higher formations of the Enid group, and correspond to the Flint Hills, Wellington, Harper, Salt Plains, Cedar Hills and Flower Pot formations of Kansas.

The following description of Aurin, Officer, and Gould[6] gives, in a general way, the characteristics of these formations.

STILLWATER FORMATION

Throughout a considerable part of the area of the outcrop of the Stillwater in central Oklahoma the exact location of neither the base nor the top of the formation has been accurately mapped at this time. The equivalents of the Stillwater in southern Kansas and in Osage and Kay counties, Oklahoma, consist of a series of limestones and shales which constitute the Flint Hills named, in ascending order, as follows: "Cottonwood limestone and Garrison shale of the Council Grove group, the Wreford limestone, Matfield shale, Florence flint, Fort Riley limestone, Doyle shale, and Winfield limestone of the Chase group, and the Luta limestone, Enterprise shale, and Herington limestone members of the Marion formation of the Sumner group.

As one passes south these various beds begin to lose their identity in the region of the Arkansas River in southern Osage,

6. Op. cit. pp. 792-799.

northeastern Noble, and Pawnee counties. By the time the color change line has been reached the limestones are thinning rapidly and are being replaced by sandstones, while the shales begin to change their color from gray to red. Still farther south the limestones disappear and the entire formation is found to consist of alternating beds of red shales and red and gray sandstones. This is typical Stillwater, as exposed at the type locality, Stillwater, the county seat of Payne County.

The combined thickness of the various Kansas formations making up the Stillwater as exposed on the surface in southern Kansas and northern Oklahoma approximates 540 feet[7]. In general, these beds are believed to thicken to the south. A fair estimate for the thickness of the Stillwater in east-central Oklahoma would probably be about 800 feet.

WELLINGTON FORMATION

The Wellington formation, first described by Cragin[8], consists of gray to bluish and drab shales with numerous thin beds of gray "Mud-stone." The same general conditions also obtain in a considerable part of Kay County, Oklahoma. At the color-change line, however, beds of red sandstone appear, and the color of the shales changes from gray and drab to red. The characteristic "mud-stones" persist, however, to the latitude of Perry, and the Wellington type of topography is still found as far south as Mulhall. South of Cimarron River practically all the original Wellington characteristics have been lost.

The Wellington formation in Kansas rests on the Pearl shale member of the Marion formation, but since the Pearl shale member cannot be readily differentiated from the Wellington in Oklahoma it is mapped with the Wellington and, for purposes of mapping, the boundary is placed at the top of the easily recognized Herington limestone. The top of the Wellington is the base of the lowest heavy sandstone of the Garber formation.

The thickness of the Wellington, including the Pearl shale in northern Oklahoma, is approximately 670 feet.

GARBER SANDSTONE

The name Garber, which for several years has been employed by local geologists in the region under discussion, is here proposed to include a series of red clay shales, red sandy shales, and red sandstones lying above the Wellington. The name is from the town of Garber, in eastern Garfield County, Oklahoma, where the formation is well exposed.

Geologists working in the field have learned to distinguish in a general way a lower shaly phase and an upper sandy phase of the Garber formation, and these phases are sometimes spoken of as the "lower Garber" and "upper Garber." In order to avoid the use of the terms "lower" and "upper" the following classification is used.

Lucien shale member

The lower part of the Garber sandstone exposed throughout a considerable part of eastern Garfield, western Noble, and western Logan counties is composed largely of red, more or less fissile or laminated clay shales with several ledges of red sandstone.

7. Gould, Chas. N., Index to the Stratigraphy of Oklahoma, Oklahoma Geol. Survey, Bull. 35, pp. 80-85, 1924.

8. Cragin, F. W., The Permian system of Kansas: Colorado Coll. Studies, Vol. 6, pp. 18-26, 1896.

One of these ledges generally occurs at the base of the Lucien member, otherwise the base of the Garber sandstone. Other beds of red sandstone, more or less lenticular in nature, occur at higher levels, but the Lucien member as a whole is made up chiefly of red shales which are generally easily distinguishable from the blocky, red clay-shales of the younger Hennessey formation.

The thickness of the Lucien member approximates 250 feet. The beds are well exposed at the village of Lucien, in western Noble County.

Hayward sandstone member

The upper part of the Garber sandstone is named the "Hayward sandstone member" from a village in southeastern Garfield County.

This member consists for the most part of heavy ledges of massive red sandstone, more or less lenticular, generally cross-bedded and not uncommonly conglomeratic, interstratified with beds of fissile shale and sandy shale. The sandstones, in many places, weather into conspicuous cliffs. The thickness of the member approximates 350 feet.

HENNESSEY SHALE

The Hennessey is throughout a clay-shale formation, and as such is easy to differentiate from the sub- and superjacent formations which consist chiefly of sandstone. Its lower limit is the heavy sandstone at the top of the Garber, and its upper limit the base of the Duncan sandstone.

The shales of the Hennessey differ from other red shales in the lower part of the Enid group in that they are rarely fissile or laminated, but are more commonly blocky and break with a conchoidal fracture having the appearance of "joint clay". The Hennessey as a whole is also characterized by numerous bands or streaks, white or light green in color, varying in thickness from a few inches to 4 feet or more. These bands may be persistent for many miles and, in the absence of better material, serve as convenient data of reference for instrument work by geologists.

As in the case of the Garber, the Hennessey has also been divided by men familiar with its stratigraphy into lower and upper beds or members. For these members the authors here propose the names "Fairmont shale member" and "Bison banded member."

DUNCAN SANDSTONE

Cragin[9] first described the Harper sandstone in Harper County, Kansas, as follows:

"The Harper sandstones * * * * * comprise several hundred feet of more or less mottled, but prevailing dull red, or brownish-red argillaceous and arenaceous shale and sandstones, above the Wellington shales and below the Salt Plain measures."

The Harper sandstones of Kansas have been carried southward into Oklahoma where they are found to constitute the formations which in this paper are called the Garber sandstone, the Hennessey shale, and the Duncan sandstone. The uppermost of these formations, here called the Duncan has been traced south crossing Grant, Garfield, Kingfisher, Canadian, and McClain counties, where it appears to be the same as the Duncan sandstone.

9. Op. cit.

As exposed in northern Oklahoma, the Duncan consists of rather soft, friable or shaly, red sandstone. It is commonly crossbedded, locally conglomeratic, and not uncommonly interstratified with red shales. This shaly phase of the Duncan has sometimes given rise to confusion regarding the location of the contact between the Duncan and the sub-and superjacent formations, and upon this subject the authors are not yet in complete agreement. The base of the Duncan is the line of contact between the lower sandstone bed and the top of upper blocky shale bed of the Hennessey. The top of the formation in some places is difficult to locate, on account of the gradual change of the sandy phase of the Duncan into the shale beds constituting the Chickasha, as will be set forth later.

The thickness of the Duncan appears to be variable, averaging perhaps 100-300 feet. Throughout its outcrop in Kansas and Oklahoma the Duncan is generally a persistent scarp-maker, forming a row of low hills overlooking the plain to the east, formed by the Hennessey shale and equivalent formations.

CHICKASHA FORMATION

In northern Oklahoma the Chickasha is composed chiefly of gypsiferous red clay shales and thin sandstones, the clays greatly predominating. The clays contain many bands or streaks, from a few inches to several feet in thickness, of white and light-green clay. The formation is also characterized by the great abundance of "polkadot" balls, or concretions, of white and green clay, the origin of which has been the subject of much comment, but which is still obscure. The upper part of the Chickasha contains much satinspar, selenite, or concretions of gypsums.

The upper limit of the Chickasha is the base of the Blaine gypsum of the Gypsum Hills, but, as stated many years ago:[10] "The top of this formation (the Enid) is not a plane, since the gypsum beds, which mark its uppermost limits, are found to be more or less lenticular when traced for long distances."

SUBSURFACE FORMATIONS

An exceedingly complete section of the subsurface formations is available for Kay and Noble counties, but only in the eastern margin of Grant and Garfield counties has there been drilling to the Ordovician (Wilcox sand and "Siliceous lime") rocks. This horizon has been reached in a well as far west as sec. 29, T. 23 N., R. 4 W., which reached what is probably the Viola limestone at 5990-95 feet. Beyond this no data is available.

The subsurface horizons are comparatively easy of correlation because of the regularity of occurrence of a number of persistent key beds. The present practice of keeping accurate logs by means of cuttings taken at frequent intervals during the drilling of the well, augmented by core drill records in a number of areas, has given a very complete and accurate knowledge of subsurface conditions. Very accurate correlations are now possible from the time the well has reached the Foraker limestone until the "Siliceous lime" is penetrated.

10. Gould, Charles N., U. S. Geological Survey, Water-Supply Paper No. 148, p. 39, 1905.

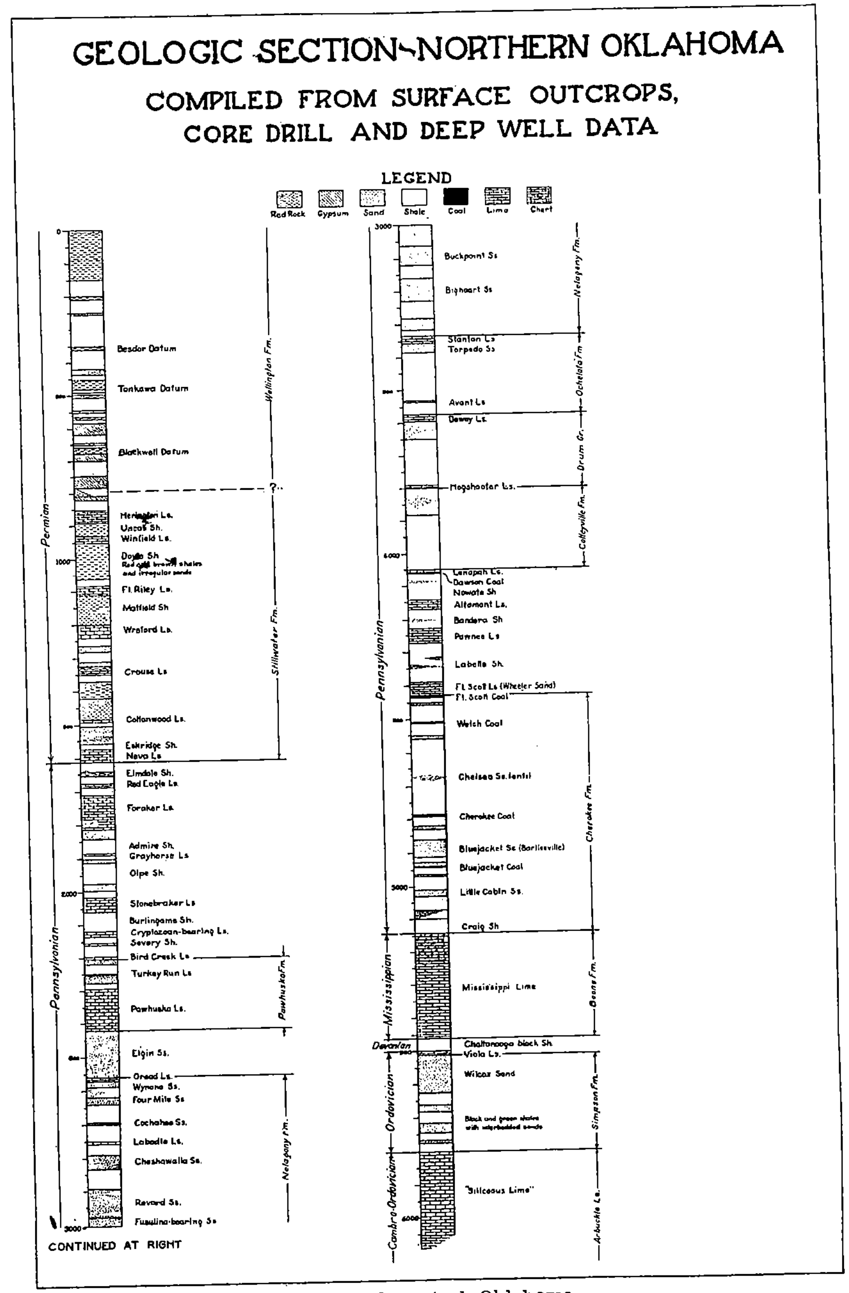


Figure 3—Geologic Section—north-central Oklahoma.

Not all of the actual subsurface formations will be described. Those formations which outcrop in the eastern part of the area (Stillwater formation) and which have been described under "surface formations" are beneath the surface farther west in Grant and Garfield counties, and will not be described here. The discussion of subsurface formations will include rocks of Pennsylvanian to Ordovician age inclusive.

PENNSYLVANIAN

The Pennsylvanian is represented by a great thickness of alternating sandstone, shales, and limestones. This series is approximately 2,500 feet thick at Braman, 2,700 feet at Garber, 3,050 feet at Ponca, 3,100 feet at Tonkawa, 3,250 feet on normal west dip just west of Ponca field and 2,800 feet at the Thomas pool. These formations thicken to the east, as is shown by a thickness of approximately 4,400 feet of Pennsylvanian shown in a general section of northern Oklahoma taken from surface and core drill data, (see Figure 3).

The Pennsylvanian represented in well logs of this area include all of the formations from basal Cherokee to the base of the Neva limestone. These need not be described here since an adequate description has been given by Gould.[11]

The common driller's names of the important horizons in the Pennsylvanian series from the base up are:—Cherokee shales, Oswego "Big lime" group, Layton sand, Tonkawa sand, Endicott sand series, Hoover sand series, Pawhuska limestone, and Foraker limestone. These will be taken up in detail under the description of the various fields. There is an erosional unconformity at the base of the Pennsylvanian.

MISSISSIPPIAN

The Mississippian series is represented by an average of about 300 feet of Mississippi lime, which grades from a gray to a dark brown and black cherty limestone, with a variable thickness of residual chert at the top. Two, and sometimes three, horizons are recognizable. In going from the Ponca City field to the Blackwell field the interval between the Oswego and the Mississippi lime increases to about 450 feet midway between these fields. A little production has been obtained in the upper chert horizon of the Mississippi lime.

DEVONIAN

The Chattanooga shale, here placed in the Devonian, has been placed in the Mississippian by some writers. The formation in this area is composed of black carbonaceous shale containing a considerable amount of pyrite.

ORDOVICIAN

This system includes about 15 feet of "white lime," which has been correlated with the Viola limestone, and the Simpson formation. Most

11. Gould, Chas. N., Index to the Stratigraphy of Oklahoma: Oklahoma Geol. Survey, Bull. 35, 1925.

of the wells that have gone through the Simpson find it to be on an average, 300 feet thick. The upper member of the Simpson, known as the Wilcox sand, is made up of pure sand with well rounded and frosted grains, and a few scattered thin partings of green shale. It is distinguished from the Pennsylvanian sands by the total absence of mica which is present in all the higher sands, and the character of the sand grains. The remainder of the Simpson is made up of alternating beds of black and green shale and sandstone, the sands being much thinner than the Wilcox but of a similar character.

CAMBRO-ORDOVICIAN

Below the Simpson formation there is an unknown thickness of "Siliceous lime," or Arbuckle limestone. This formation has not been penetrated deeper than 1,000 feet in this area.

The name Siliceous limestone was applied by F. L. Aurin[12] to the massive beds or bed of dolomite of Ordovician age, found immediately underlying the sands and shales of the Simpson formation in northern Oklahoma.

This formation varies from white to brown in color and from dense to coarsely crystalline in texture, as found in drill cuttings and in occasional fragments obtained when a well is shot. No quantitative analyses are available but from rough tests made on samples from various wells the magnesium content is estimated to be somewhere between 20 and 40 per cent and wherever tested is consistent throughout the entire thickness of the formation.

Chert nodules of various sizes are scattered irregularly through this dolomitic mass. In most cases this chert is composed of a mass of oolites, which in cross section generally show radiating and branching channels rather than the concentric layers of common oolites. In a few cases, zones are found in the Siliceous lime which are composed of fine, perfectly formed crystals of brownish dolomite in a white, porcellanous chert matrix. These fine crystals and the oolites are most abundant in the "pay zones" in certain fields, while in other localities the drill cuttings show only a fissured or channeled condition where oil is encountered in the dolomite. These fissures are lined with perfectly formed crystals of dolomite showing that solution and deposition has taken place after the deposition of the beds and it is this secondary solution which is probably responsible for the porosity of the "pay zones."

The drill cuttings of this dolomite have a characteristic sugary appearance which frequently leads the drillers to log it as sand or sandy lime. This misconception is apparently confirmed by the fact that the chert content is usually sufficient to "cut" the bit, and also by the fact that the dolomite effervesces only slightly in cold acid.

12. Aurin, F. L., Pre-Pennsylvanian oil and gas horizons in Kay County, Okla.: Bull. Amer. Assoc. Pet. Geol., Vol. 4, No. 2, 1920.

However, in hot acid it effervesces rapidly and under a glass of 15 power or higher the typical rhombohedral cleavage blocks of the dolomite are easily seen. The chert is also easily differentiated from sand by the conchoidal fracture and the fact that it is opaque or nearly so.

STRUCTURE AND GEOLOGIC HISTORY

Oil accumulation in this area, with one or two minor exceptions, is associated with distinct structural features in contrast with some of the fields in eastern Kansas and the Okmulgee and Osage districts of Oklahoma which produce from lenticular sands not associated with structure.

Our knowledge of the geologic history of the subsurface formations of this area, as furnished by well cuttings and records, extends back to early Ordovician. With one exception wells have not gone deeper than the upper 300-400 feet of the Siliceous lime (Cambro-Ordovician). This exception, a well in T. 28 N., R. 3 E., reached the arkose at approximately 4,800 feet, after penetrating 1,010 feet of Siliceous lime.

The deposition of the first sediments laid down upon the granite occurred from Cambrian to the close of Hunton time, and includes the upper Arbuckle, Simpson, Viola, Sylvan, and Hunton formations. This period of sedimentation was followed by a period of emergence when the above formations were tilted and eroded.

The next structural movement affecting the formations occurred in the pre-Chattanooga time and is thought to have been caused by the Ozark uplift and as a result the pre-Chattanooga formations were tilted in a southwest direction. This uplift was followed or accompanied by erosion which truncated the upfolded formations from the Simpson to the Sylvan (and possibly Hunton), leaving their surfaces exposed in broad belts. This uplift has caused a regional dip of 55 feet per mile through the Ponca City field and 42 feet per mile through the Garber area. It is possible that there was some movement in the granite basement before this time, but there is not sufficient evidence available at the present time to discuss this phase of the problem.

Following the pre-Chattanooga period of uplift the formations from the Chattanooga black shale to the top of the Mississippi lime were deposited, after which there was another period of emergence accompanied by folding, faulting and erosion.

This structural movement, from present available data, occurred at the close of Mississippian time. There is no doubt as to the pre-Pennsylvanian age of the movements. There are two distinct faults, one in the Thomas pool and one in the Tonkawa area, that have involved the pre-Pennsylvanian rocks. In these pools there is also evidence of erosion at the close of the Mississippian time which has in most cases concentrated the upper chert member of the Mississippi lime on the flanks of the folds. On the crests of the Thomas and Tonkawa folds the drill passes from the Cherokee shales into the "white lime" (Viola limestone) or Wilcox sand.

These movements have resulted in two major lines or trends of folding in this region. The more positive one (here named the Blackwell Anticline) includes from north to south, the Dilworth, Blackwell, Retta, Thomas and Garber pools. This trend of folding is believed to be an extension of the granite ridge or Nemaha Mountains of Kansas. With one exception, as already mentioned, granite has not been encountered in any of the wells in this area. The other line of folding (named the Ponca Anticline on the map, Plate I), believed to be an extension of the Beaumont and Dexter folds of Kansas, passes through the Mervine and Ponca pools. The Tonkawa and Billings pools seem to lie on a separate trend from these folds. This ridge is terminated by the fault on the north edge of the Tonkawa field, and if extended to the north, encounters the large syncline which lies between the Ponca and Blackwell folds. It is probable that the Ponca anticline is younger than the Blackwell anticline because erosion has not here removed the Mississippi lime.

An interesting feature involving structure is found in a line of domes found between Tonkawa and Peckham. These folds are situated in the regional syncline between the Ponca and Blackwell anticlines and are not connected with the Tonkawa structure. These structures have practically no production while production is found in the fields to the east and west.

All of the folds in this area were eroded contemporaneous with or subsequent to uplift, which resulted in the exposure of the older formations on the crests of the anticlines. The amount of strata removed varies from a part of upper Mississippian to the entire section from the top of the Mississippi lime to the upper Siliceous limestone, the amount of removal depending upon the amount of the structural relief (see table, page 22). The whole section has been eroded from the crest of the Garber structure, where approximately 750 feet of sediments have been removed.

The character of the rocks at the surface during this pre-Pennsylvanian erosion interval was such that anticlinal valleys were not formed. Had the Mississippian been composed of thick shales and interbedded hard, resistant limestones and sandstones it is probable that anticlinal valleys would have resulted. The section, being made up of large thicknesses of resistant beds and a few thin beds of the less resistant shales resulted in anticlinal hills. These hills in turn reflected themselves in the subsequent formations resulting in the present surface structures. The possibility of subsequent folding in the formation of surface structure should be considered, as it is not probable that all of the surface structure is due to the reflection of these buried hills. There is Permian or post-Permian faulting in the Retta area, and some indications of post-Permian faulting is found in the Braman area. However, the most important factor in the formation of surface structure is the differental deposition and settling of the Pennsylvanian and younger sediments on this old topography.

Effects of pre-Pennsylvanian uplift and erosion.

Pool	Structural Relief of Ordovician	Present Topographic Relief of Pre-Pennsylvanian Surface	Difference, or Thickness Removed by Erosion	Interval Between Base of Oswego and top of Pre-Penn-Surface
GARBER	1750	1000	750	50
RETTA	1000	550	450	50
OTSTOT	1000	650	350	75
DILWORTH	950	600	350	100
DEER CREEK	1250	800	450	100
TONKAWA	900	500	400	185
S. BILLINGS	1100	750	350	100
PONCA	500	375	125	325
MERVINE	525	400	125	150
THOMAS	1000	600	400	50

Following this hiatus came the period of deposition during which all of the Pennsylvanian and Permian sediments were deposited. In Cherokee time a mantle of shale containing some fine grained sands (Burbank) was spread over the entire area. It attained considerable thickness in the valleys and was very thin on top of the highest hills which were at times islands in this early Cherokee sea. Before the close of Cherokee time all the pre-Pennsylvanian islands had been completely submerged, as evidenced by the fact that the Oswego-Big lime series extends without interruption over the entire area. The minimum shale interval between the base of the Oswego and the erosion surface on top of the highest pre-Pennsylvanian hill is about 50 feet.

In this area there was a period of practically uninterrupted deposition from Oswego to the youngest Permian beds. The structure of these beds is a modified impression of the underlying pre-Permian topography. Little is known in detail of the history of the region after this time, except that the area has been distinctly positive and undergoing erosion. It may be that the Tertiary alluvial fan, which spread eastward from the Rocky Mountains once covered this region, and was removed by subsequent erosion. Structurally there has been some faulting of the Permian beds, as in the Retta area, of which little is now known.

PONCA FIELD

The Ponca field is located in secs. 4, 5, 7, 8, 9, 17, 18, and 19, T. 25 N., R. 2 E., Kay County.

HISTORY

This was the first field to be discovered in the north-central Oklahoma district. In December, 1907, E. W. Marland, a Pennsylvania oil operator, with others visited Kay County to investigate the possibilities for oil. He was impressed with the Ponca area, and after securing a lease from Miller Brothers started a well in February, 1909. This was the first well west of the Osage, consequently many difficulties were encountered in moving in material. The nearest supply house was located at Tulsa, 120 miles distant, and from there the heavy material was transported. The initial well never reached the producing sand, was abandoned, and another started five miles distant. This second well, a gasser, came in in the spring of 1910. At this time the 101 Ranch Oil Co. was organized by Marland and his associates, which continued operations until 1917. This company developed the "1,500 foot" sand, drilling eight gas wells before oil was found. The first oil well in the field was brought in as the Willie Cry No. 1, SE.¼, sec. 8, T. 25 N., R. 2 E. and made 120 barrels in the "1,500 foot" sand after being shot.

In 1917 the Marland Refining Co. took over the entire acreage of the field and developed the "2,100 foot" sand, and next year the "3,800 foot" sand.

STRUCTURE

The oil accumulation in the Ponca field is found in a pronounced anticlinal fold (Plate III) trending northeast-southwest. The surface structure is somewhat obscure, but the folding becomes more pronounced with depth. The approximate structural relief on the Wilcox is 500 feet. The east dip from the crest of the structure is extremely steep, approximately 400 feet for the first half mile on the Mississippi lime and 150 feet on the "1,300 foot" sand. The interval between the base of the Oswego and the top of the pre-Pennsylvanian surface is 325 feet which is probably the greatest to be found in the entire area.

PRODUCTION

There are a number of producing horizons in the Ponca field. The following table shows the various sands.

Producing sands in the Ponca field.

Depth	Thickness	Production	Horizon
500	20	*10	Basal Permian
900	18	*8-10	Grayhorse(?)
1,300	30	*10	Bird Creek, Turkey Run
1,500	18	40-150	Ponca (U. Hoover).
1,600	15	Good Show	L. Hoover
1,800	16	30-200	Endicott
2,100	40	30-200	Bigheart
3,600	50	75-150	Mississippi Lime
3,900	40-90	100-800	Wilcox

Average gravity 40.6 *Million feet of gas.

NEWKIRK-MERVINE FIELD

The Mervine field is located in secs. 2, 3, 10, 11, 14, and 15, T. 27 N., R. 3 E. and sec. 35, T. 28 N., R. 3 E., Kay County.

HISTORY

The first important oil well was drilled in this field in 1913 on the Murdock farm in the NE. cor. SE.¼ sec. 2, T. 27 N., R. 3 E. and had an initial production of 100 barrels. This is the first oil well to be drilled on a published structure, which was made by the Oklahoma Geological Survey in 1913. The discovery well was followed by a number of good wells which made from 500 to 1,000 barrels each from the "1,000 foot" sand. These wells did not hold up their production, and interest in the area lagged until July, 1918, when the Carter Oil Co. and the Southwestern Petroleum Co. drilled a well on the McClasky farm in NW. cor. SW.¼, NE.¼ sec. 15, T. 27 N., R. 3 E. which made a good producer in the "3,200 foot" sand. In December of the same year the Carter-Hays No. 3, in sec. 15, made an initial production of 2,000 barrels from around 3,100 feet. The production of this well has held up remarkably considering the rapid decline of wells subsequently drilled.

Late in 1916 Marland opened the North Newkirk field with a 28,000,000 foot gas well on the McMichael farm in sec. 17, T. 28 N., R. 3 E. The gas from this well was used to supply the towns of Ponca City, Newkirk, Kildare, and Tonkawa for about three years. The finding of gas lead to further drilling and in July, 1919, Marland's No. 1 Hieberson made 200 barrels in the top of the Mississippi lime. The same year Marland drilled a 500 barrel well in sec. 16, T. 29 N., R. 3 E. in the Chilocco district.

STRUCTURE

The structure of the Mervine is a continuation of the Ponca fold and lies on the main line of folding extending south from the Beaumont and Dexter folds in Kansas. (See Plate I and Fig. 4). This structure was mapped in 1912 by Ohern and Garrett of the Oklahoma Geological Survey after being discovered by Gould in 1901, while mak-

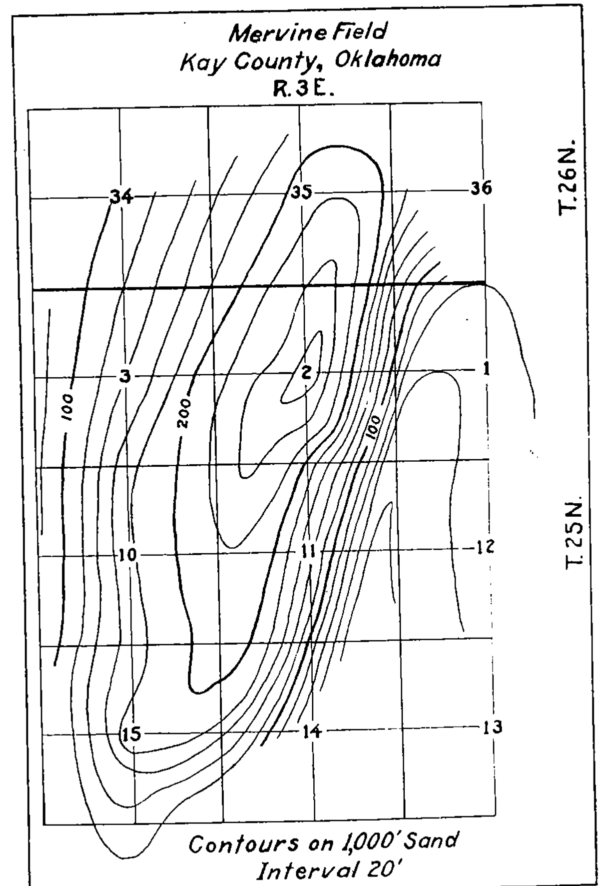


Figure 4—Structure map of Mervine field (1,000 foot sand horizon).

ing a reconnaissance of this general area. The fold has a structure relief of 535 feet on the Wilcox and an east dip of 220 feet in a half mile on the "1,000 foot" sand in sec. 2, T. 27 N., R. 3 E. The axis of this fold trends about N. 20° E., with the crest in the center of section 2.

Northeast of Newkirk in secs. 8 and 17, T. 28 N., R. 3 E., is a small dome about a mile in areal extent and which is also a topographic high, being almost coincident with the highest hill in the region.

PRODUCTION

There are five producing sands in the Mervine pool. The "1,000 foot" or Mervine sand is continuous over the pool and produces on the highest part of the structure. The next three sands are productive only locally. The deep sand, 3,100 feet, is the equivalent of the Burbank (?) and produces in the southern part of the field.

Producing sands in the Mervine pool

Depth	Thickness	Production	Horizon
1,000	26	20-400	Newkirk
1,250	15	10-41	Hoover
1,500	15	50-250	Endicott(?)
1,800	22	5-40	Stalnaker(?)
3,100	50	50-400	Burbank

Average gravity 40.6

BLACKWELL FIELD

The Blackwell field is located in secs. 29, 30, 31, and 32, T. 29 N., R. 1 E., secs. 5, 6, 7, 8, 17, 18, 19, 20, 29, and 30, T. 28 N., R. 1 E,, and in secs. 1, 12, 13, 23, 24, 25, 26, 35, and 36, T. 28 N., R. 1 W., Kay County.

HISTORY

In 1912 the north end of this field was developed by Marland and others which resulted in 21 gas wells out of 37 completions. Previous to this there had been some development by local people, but much difficulty was experienced in drilling through the red beds. Real interest in the field started in 1914, when one oil well making 600 barrels and a number of good gas wells were drilled. This first oil well was located in NE. cor. sec. 29, T. 29 N., R. 1 E. and since then the field developed to the south with the bringing in of a number of good wells. The Duluth-Oklahoma Company drilled a well in sec. 1, T. 28 N., R. 1 W. which started off with a 2,000 barrel production and which produced a half million barrels within a year. The field was finally extended five miles south of the first well. It is not known who discovered the field, but it was mapped by L. E. Trout for the Oklahoma Geological Survey.

STRUCTURE

The surface structure is very hard to map because of the indefinite nature of the outcrops of shale occurring in the area, and the complex nature of the fold as shown by subsurface work. The structure (Fig. 5) is made up of two highs in north-south alignment, separated by a saddle. The fold is an extension of the granite ridge of Kansas and is on the Garber, Thomas, Otstot line of folds in Oklahoma.

PRODUCTION

There are at least two producing horizons in this field, ranging from lower Permian to Ordovician (Wilcox) in age.

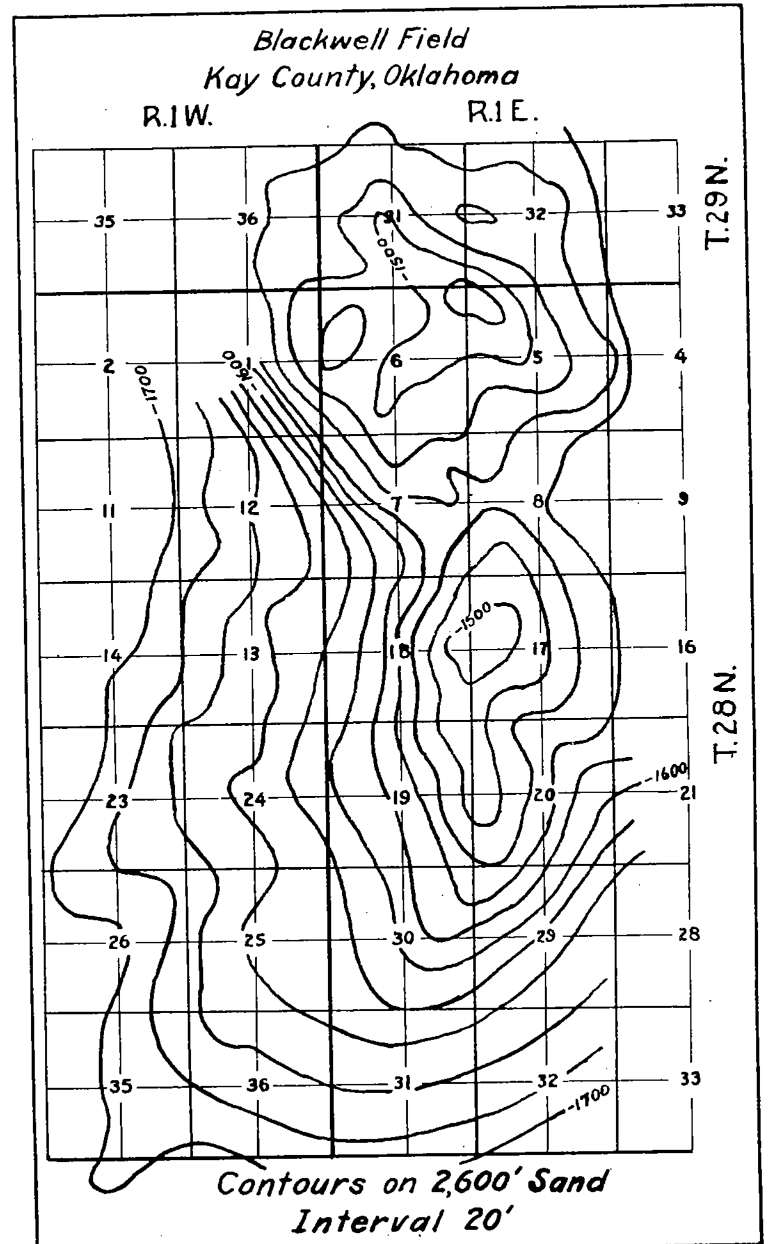


Figure 5—Structure map of Blackwell field (2,000 foot sand horizon).

Producing sands of the Blackwell field.

Depth	Thickness	Production	Horizon
700	6	*10	Just above Neva
1,400	20	*2-35	Newkirk (?)
1,600	10	100-450	Ponca (Upper Hoover)
1,750	15	100-1,350	Lower Hoover
1,900	20	20-1,200	Endicott (?)
1,950	13	to 1,000	Revard (?)
2,200-2,300	32 & 23	*5-20	Stalnaker (Tonkawa)
2,600	75	*5-20 100-2,000	Layton
3,300	100	*3-45	Wilcox

Average gravity 38. *Million feet of gas

BILLINGS FIELD

The Billings field is located in secs. 15, 16, 21, and 22, T. 23 N., R. 2 W., Noble County.

HISTORY

This field is the result of drilling in NE. cor. NW.¼ secs. 22 and 23, on a structure mapped by geologists of the Midco Petroleum Co. of Tulsa. It produced 250 barrels from a sand at 2,136 feet. In June, 1919, this well was deepened and produced 50 barrels at 2,351 feet, and in September it was deepened a third time to 5,031, where it was abandoned. A show of oil between 4,100 and 4,200 feet caused the drilling of another well which produced 35 barrels at 4,176 feet. Two wells to the Wilcox made small amounts of oil. The pool covers a small area and development was slow.

STRUCTURE

A subsurface contour map of this field shows a well defined dome, which, unlike most fields in this area does not have a tendency to elongate in any direction. The closure of the dome amounts to approximately 500 feet covering an area of 10 square miles, but the producing area is limited to about one square mile with a closure of about 250 feet.

PRODUCTION

Oil and gas are found at a number of horizons in this field. Many of the wells had a large initial production, but speedily declined to a settled production averaging 15 barrels per well.

Producing sands in the Billings field.

Depth	Thickness	Production	Horizon
450	20		Herington
625	10	*1-3	Above Fort Riley
725	5		Matfield Shale
950	6	*1-6	Below Crouse Limestone
2,050	30	100-1,500	U. Hoover
2,200	50	3-10	Lower Hoover
2,400	25	50-100	U. Nelagony formation
2,750	75	50-100	Tonkawa
4,100	65	35 (1 well)	Mississippi lime

Average gravity 43. *Million feet of gas

Dry holes have been drilled on all sides of production so that the prospects for extensions of this pool are not good. The fact that the two Wilcox wells did not yield production of any consequence shows that the field has been completely developed.

GARBER FIELD

The Garber field is located in secs. 18 and 19, T. 22 N., R. 3 W. and secs. 13 and 24, T. 22 N., R. 4 W., Garfield County.

HISTORY

The discovery well on the Hoy farm in the NE. cor. sec. 25, T. 22 N., R. 4 W., was brought in by the Sinclair interests in September, 1917 shortly after the discovery of the Billings field. The "Hoy" sand named after the owner of the farm, produced 100 barrels at 1130-56 feet. The development proceeded fairly rapidly following the completion of the Sinclair well. The Roxana Petroleum Corpora-

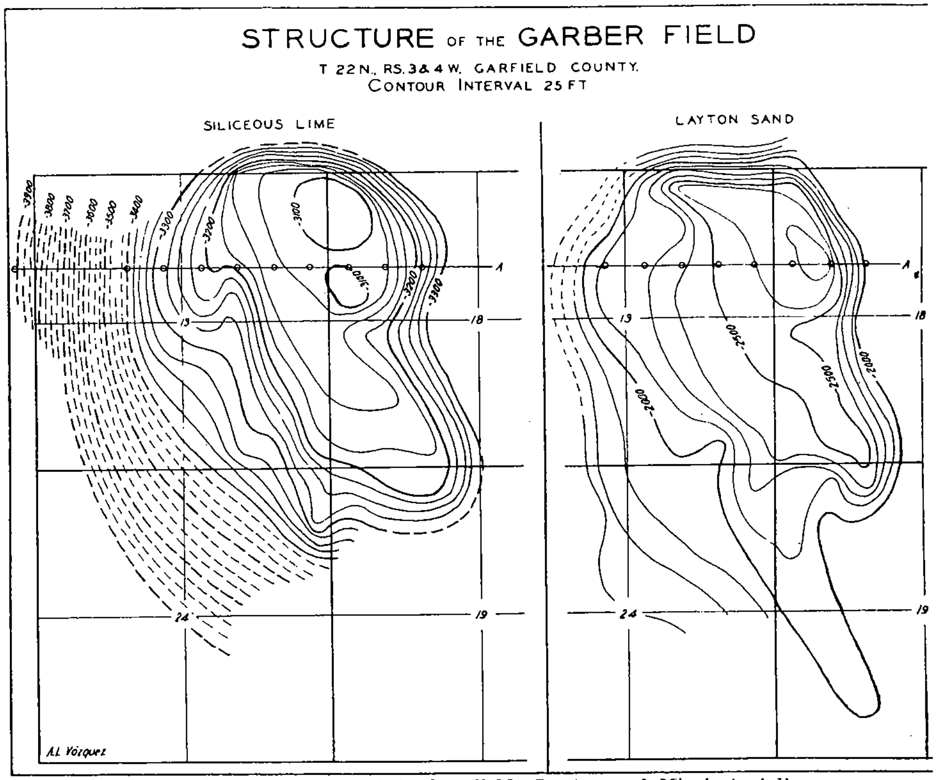


Figure 6—Structure maps of Garber field (Layton and Mississippi lime horizons).

tion, Healdton Oil & Gas Co., Cosden Oil & Gas Co., Marland Refining Co., and Atlantic Petroleum Co., all had tracts close to the discovery well and immediately started drilling.

STRUCTURE

The location of the first drilling in the Garber area was the result of the indication of subsurface structure mapped on the surface formations. The outcrops are in cross-bedded sandstones with intervening shales, which vary greatly in horizontal extent. However, it was possible to map the presence of the structure in a general way, but its extent was unknown before drilling. Subsurface structure (Fig. 6 and Plate IV) in the shallow zones is extremely difficult of solution because of the irregular and lenticular character of the sand bodies. Perhaps the true interpretation of the Garber structure can be obtained only from data gathered from the deeper sands.

The structure as worked out on the top of the Siliceous lime is apparently a topographic high on which the geologic section, from just below the Oswego-Big lime horizon to and including some of the Siliceous lime, is absent. The Mississippi lime, Chattanooga shale, Viola limestone, Simpson formation, and a part of the Siliceous lime were removed during this erosion interval. The thin section of Cherokee shales present is due to the fact that this old hill was an island, which was not submerged until late Cherokee time, giving about 60-75 feet of Cherokee shale over the crest of the high. This results in the contact between the Siliceous lime and the Cherokee shale. The geologic history of the Garber area is much the same as that of the Thomas and Tonkawa areas. The Wilcox is present only on the flanks of the fold. This contact between the Wilcox and the Siliceous lime roughly follows the 3,275 foot contour line, as shown on the accompanying cross-section (Plate IV).

PRODUCTION

The wells in the shallow lenticular sands decline rapidly to about 15 barrels per well while the production in the deeper and more regular sands is more steady. The field has been a profitable one because of the shallowness of the sands and the large number of producing horizons.

The largest initial production of any well in Oklahoma is the Sinclair Oil and Gas Co.'s Hartley No. 27 in the NW.¼ NW.¼ sec. 18, T. 22 N., R. 3 W. This well reached the Siliceous lime at 3,085 feet and produced as high as 27,000 barrels daily during its early history.

Producing sands in the Garber field.

Depth	Thickness	Production	Horizon
825	8		Winfield
1,050	20	20-150	Hoy sand
1,360	10		
1,470	15	20-150	Above Foraker
1,740	10		
2,020	12	15-100	U. Pennsylvanian
2,100	12		
2,200	5	25-200	
2,315	20		U. Hoover
2,500	15		M. Hoover
2,560	35		L. Hoover
2,750	45		Endicott
3,025	25		U. Tonkawa
3,070	50		L. Tonkawa
3,600	90		Layton
4,160	20		Oswego—Big Lime
4,250	?		Wilcox on flanks of fold
4,260	50+	5-10,000	Siliceous lime

EAST BILLINGS FIELD

The East Billings field is located in secs. 20, 29, 30, 31, and 32, T. 24 N., R. 1 W. in Noble County. This field is sometimes known as the North Billings field.

HISTORY

In 1916, shortly after the discovery of the Billings pool, operations were started on what was believed to have been a continuation of the line of folding running northeast. The U. S. Geological Survey had mapped a structure of sections 17 and 20, and the Humphreys Petroleum Co. started several wells which failed to produce, although some gas was encountered.

The Midco Petroleum Co. in November 1919, drilling in the SE. cor. sec. 30, brought in a 150 barrel well from a sand at 2,000 feet, which was the discovery well of this field. The pool is small, about one square mile in area, and is completely developed.

STRUCTURE

The Billings production is on a small dome, less than a square mile in area, situated on the major fold running through the Tonkawa and South Billings fields. There are sufficient surface dips to show the presence of the reversal.

PRODUCTION

Most of the production is obtained from the Upper Hoover sands just below 2,000 feet. Some gas has been found at 600 and 2,675 feet, and only a show of oil in the Mississippi lime at 4,300 feet.

DEER CREEK FIELD

The Deer Creek field is located in secs. 14, 15, 22, 23, 26, and 27, T. 27 N., R. 3 W., Grant County.

HISTORY

The discovery well is in NE. cor. SE.¼ sec. 22, completed in July, 1920 and produced about 18 million feet of gas from a sand at 2,440 feet. This well was later deepened to 3,350 feet and made 10 barrels of oil. The first oil produced came from the Western State's No. 1, Swaggert in SW. cor. SE.¼ SE.¼ sec. 15, which made 450 barrels at 2,950 feet. The Prairie Oil & Gas. Co. offset to this sand made 960 barrels at 2,925 feet.

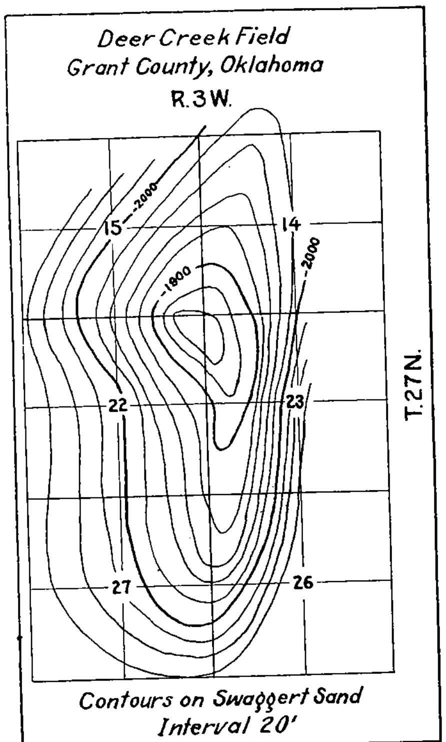


Figure 7—Structure map of Deer Creek field (Swaggert horizon).

STRUCTURE

The Deer Creek structure (Fig. 7) is a small elongated dome, about three times as long as wide, with the axis extending almost directly north and south. This structure is one of the most sharply folded in the entire area having 1,250 feet of structural relief on the

Ordovician, which is probably the cause of the large amounts of gas and small amounts of oil produced.

Producing sands of the Deer Creek field.

Depth	Thickness	Production	Horizon
1,300	23	* 5-15	Above Neva
2,000	10	*12-15	Newkirk (?)
2,400	20	*10-15	Lower Hoover
2,900	30	960	Swaggert (Tonkawa)
3,000	10	15	Layton
3,900	20	Gas	Wilcox

*Million feet of gas.

TONKAWA FIELD

The Tonkawa field is located in Tps. 24 and 25 N., R. 1 W., Kay and Noble counties.

HISTORY

The Tonkawa field dates from June, 1921, when school land well No. 1, in NE. cor. sec. 16, T. 24 N., R. 1 W., was completed at a depth of 2,661 feet with an initial production of 850 barrels. The second well was completed three months later with an initial production of 3,300 barrels. These wells were in the Tonkawa sand. The fourth completion was a dry hole which was due to a tightly cemented sand. Dry holes were also drilled in NW.¼ sec. 10 and SW.¼ sec. 3, and the real importance of the field was not apparent until almost a year later when Carmichael No. 1, SW. cor. NE.¼ sec. 3 was brought in for 850 barrels in the Lower Hoover sand.

Development proceeded at a rapid rate during the latter part of 1922 and the first half of 1923. All of the wells at this time were producing from Pennsylvanian formations.

Development of the deeper sands in this general area began with the completion of Slick No. 1A, SW. cor. sec. 35, T. 25 N., R. 1 W. in April, 1924. Well log correlations with deep tests placed the producing horizon in basal Cherokee or near the top of the Mississippi lime. Evidence later has led to the conclusion that the Mississippi lime is absent and that the Wilcox is found directly beneath the Pennsylvanian shales, as is the case in such fields as Eldorado (Kansas), Cushing and Blackwell.

In the following paragraphs by Glenn C. Clark[13], the stratigraphy and structure of this field is very clearly given.

13. Clark, Glenn C., Wilcox sand production, Tonkawa Field, Oklahoma: Bull. Amer. Assoc. Pet. Geol., Vol. 10, No. 9, pp. 885-891, 1926.

STRATIGRAPHY

Production at Tonkawa above the Wilcox sand is from five sand horizons included in a zone 750 feet in thickness, the top of which is 900 feet below the Pennsylvanian–Permian contact and the base about 1,450 feet above the base of the Pennsylvanian. This zone of producing sands is correlated with that part of the Osage County surface section between the Big Heart and Elgin sandstones. An average thickness of Permian over the higher part of the structure is 950 feet.

The Tonkawa sand, found at a depth of 2,450 or 2,500 feet, is the deepest producing horizon of the Pennsylvanian sands. The only prominent sand between the Tonkawa and Wilcox is the "3,100-foot" sand, which may be correlated in a general way with the Layton sand of the Cushing district.

The Oswego-Big Lime series is about 200 feet thick and is made up of prominent limestone beds. The individual members, however, are not easily correlated from well to well. The Cherokee shale is approximately 265 feet thick, with a persistent red shale bed about 215 feet below the base of the Oswego-Big Lime series. This red shale lies some 50 feet above the unconformity between basal Cherokee shale and the older formations.

The Mississippi lime on top of the structure is absent and increases in thickness toward the sides up to 150 feet in wells along the western edge of the field. The normal thickness in this general area to the east, where not influenced by folding, is about 300 feet. The upper 50 to 75 feet are light-colored chert, commonly called the "chat" producing horizon; the remainder is dark gray to dark limestone.

Underlying the Mississippi lime is about 30 feet of black shale, generally recognized as Chattanooga. This shale does not cave like the dark shale found just above the Mississippi lime.

Overlying the Wilcox sand and just below the Chattanooga shale is a light-colored, crystalline limestone about 30 feet in thickness. This limestone has the same characteristics as its equivalent in the Okmulgee district, the "White lime," and is so called at Tonkawa. It is correlated with upper Viola of the Arbuckle section. The lower part of this formation produces some oil. In some cases the upper part carries water.

The Wilcox sand varies from the tight quartzitic type to the loosely cemented, clear, well-rounded sand, characteristic of Wilcox over Kansas and Oklahoma. As found in the few wells that have been drilled into the Siliceous lime below, the Wilcox has a thickness of 280 feet. No attempt is made to subdivide the Wilcox except in a general way, based partly on producing zones. Due to the difficulty in securing samples from flowing wells, little is known as to whether correlations may be made from well to well on lithologic characteristics of horizons within the upper, productive part of the Wilcox. As in many other fields, the green shale formation divides the upper and lower Wilcox but, in the writer's opinion, this is the only means of subdivision at the present time.

The first pay zone includes about 40 feet of sand immediately below the "White lime" and the second includes that between 60 to 120 feet in the sand. There seems to be a non-productive zone of 20 to 30 feet in thickness between these two pay horizons. The upper 100 to 120 feet of Wilcox sand have no shale breaks of consequence. Immediately below this is found a dark shale bed about 30 feet thick. In general appearance this shale is not unlike the Chattanooga, but upon careful examination shows a

certain resemblance to the green shale associated with the Wilcox sand. Included between the base of this shale and the top of the Siliceous lime are interbedded sand and dark shale beds. No increase in production has been found in this lower phase of the Wilcox.

The uncommon amount of shale associated with the Wilcox sand probably is an important factor in the high oil recovery at Tonkawa. The fact that this shale is much darker in color than the ordinary green shale of this horizon is also significant in this respect.

The Siliceous lime has proved productive in two wells, Gaume 14 W, and C. C. Endicott 8 W, but the results have indicated that large production is not to be expected from this horizon. Experience in other fields has been that where either the Wilcox sand or the Siliceous lime is highly productive little may be expected from the other.

STRUCTURE

The Tonkawa structure lies between the alignment of granite-ridge structures including Eldorado, Oxford, Blackwell, Retta, Thomas, and Garber and the less prominent line of folding through the Beaumont, Dexter, Newkirk, and Ponca fields. Though apparently not connected with either of these, it has a close resemblance to the typical granite-ridge structures. (See Plates I, V, and VI).

The major part of the folding connected with the Tonkawa structure must have taken place at the close of Mississippian or during early Pennsylvanian time. The presence, in the immediately surrounding area, of Mississippi lime in approximately full thickness would indicate that conditions were stable during the time of its deposition. This folding and the faulting along the northeastern edge of the field were probably a part of the same general movement. Subsequent erosion removed the Mississippi lime from the higher part of the fold and the white lime from the extreme peak. After this period of erosion, followed by submergence, Pennsylvanian sediments were deposited over the truncated edges of the pre-Pennsylvanian formations.

The topography of this erosion surface was reflected in diminishing degree as deposition continued. A structure map contoured on any Pennsylvanian horizon would represent, in a general way, this topography. A comparison of the structure map contoured on the lower Hoover sand (Plate V) with that contoured on the white lime (Plate VI) is, excepting in degree of dip, essentially a comparison of the pre-Pennsylvanian topographic map with the structure map of the pre-Pennsylvanian formations. Attention is called to the difference in size and apparent difference in lateral position of the area inclosed within the highest contour in the comparison of the two structure maps. As seen in the cross-sections (Plate VI), the wedge-shaped remnant of Mississippi lime along the western flank of the fold has been largely responsible for these differences. Such influence on the east side is removed by the fault of over 300 feet throw. It seems that the white lime "high" lies east of the lower Hoover "high," thus indicating a shifting eastward with depth. It will be noted, however, that the east dip of each begins at practically the same point, and the difference in appearance is due to width and degree of dip.

The dip of Pennsylvanian and Permian formations along the southeast side of the field is more pronounced than that along the northeast side. This steep southeast dip into a prominent syncline is continuous along the east side of the pool in secs. 29 and 30, T. 24 N., R. 1 W., and the old Billings pool in T. 23 N., R. 2 W. These three pools are located on the same general line of folding, but extensions north and south are not evident. Unfortunately, drilling has not given sufficient information on the east dip to disclose whether or not this is due to faulting.

The limit of Wilcox sand production on the southwest side of the field is defined by a contour approximately 300 feet lower than the top of the structure. The position of this contour is followed by contours on shallow sands from 50 to 80 feet down-dip. The northwest extension is the only part of the field in which the limit of Wilcox production equaled or exceeded that of the shallow sands.

PRODUCTION

Total Wilcox sand production to January 1, 1926, was 28,305,000 barrels, an average of 21,443 barrels per acre over the 1,320 acres that produced oil from this horizon. Similar production from shallow sands to the same date was 49,258,000 barrels, an average of 18,729 barrels over 2,630 acres.

Producing sands of the Tonkawa field.

Depth	Thickness	Production	Horizon
725-825 (5 sands)	5-10	*5-12	Above Neva (Hotson?)
1,350	6	(small)	
1,500	17		Bet. Foraker and Elgin
1,750	18	*10-30	(Newkirk)
1,800	16	(small)	Upper Hoover
1,825-75	48		Middle Hoover
1,950	25	*6-12	Lower Hoover
2,025	5	50-250	Carmichael
2,100	6	100–600	Endicott
2,400-2,500	100	1,000-3,000	Tonkawa
4,100	285	Av. 250	Wilcox

*Million feet of gas.

THOMAS FIELD

The following discussion by Stuart K. Clark[14] gives an excellent idea of the peculiar conditions encountered in the Thomas Pool.

LOCATION

The Thomas field is located in the center of T. 25 N., R. 2 W., Kay County, Oklahoma, about 6 miles northwest of the Tonkawa oil field.

HISTORY

The discovery well of the Thomas field, Marland Oil Company's Thomas No. 1, was drilled on the strength of structural information obtained by core drilling. It was completed in May, 1924, as a 250 barrel well in sand encountered at a depth of 2,055 feet, which is hereafter called the Thomas sand.

The drilling campaign which followed this discovery was short-lived. Only two additional producers, Twin State Oil Company's Siler No. 1, in the NW. cor. sec. 22, and Carter Oil Company's Turk No. 1, in the NE. cor. sec. 21, were found at this horizon. The other drilling wells either missed the sand entirely or found it carrying water. All of them, except Marland's Thomas No. 2, in the SE. cor. SW. ¼ SW. ¼ sec. 15, were shut down. It was drilled deeper, and in May, 1925, was completed as a 3,600 barrel well in the Wilcox sand. The top of the sand was found at 3,955 feet, and the well, as finally completed, penetrated the sand 91 feet.

A second drilling campaign was immediately begun. It resulted in the finding of eleven producing wells in the Wilcox sand, and three additional producing horizons. In the order of their discovery these horizons were: the chert at the top of the Mississippi lime, with four producing wells, the 2,600-foot, or Turk sand with two wells and a 1,900-foot sand with one well. The development of the field at the present time is practically complete.

14. Clark, Stuart K. Thomas Oil Field, Kay County, Oklahoma: Bull. Amer. Assoc. Pet. Geol., Vol. 10, No. 7, pp. 643-653, 1926.

PRODUCTION

The Thomas field has produced to date 3,000,000 barrels of oil. Its present daily average is 7,000 barrels, and its ultimate total production is estimated at approximately 4,500,000 barrels.

The major portion of the oil has come from the Wilcox sand. The initial production of the wells in this horizon ranged as high as 6,500 barrels per day. The maximum initial production of wells producing from the chert at the top of the Mississippi lime was about 250 barrels. The Turk sand wells produced about 75 barrels per day. The largest initial production from the Thomas sand was 350 barrels. The one well in the 1,900-foot sand started at 400 barrels a day but declined very rapidly.

The oil produced is the high gravity (42°-44° Baume) green oil which is characteristic of this general district. Open flows of from 10,000,000 to 30,000,000 cubic feet of gas were encountered by several wells in a sandy lime in the Permian rocks at a depth of 1,200 feet.

STRATIGRAPHY

Rocks of Permian age are found from the surface to a depth of 1,200 to 1,300 feet. They include a series of alternating gray and red shales about 450 feet thick at the top; a series of thin gypsums or anhydrite beds (logged as limestone by the drillers) separated by gray shales, with a total thickness of 150 feet; and a series of alternating limestones and red shales about 600 feet thick, with the Herington limestone at the top and the Neva limestone at the bottom.

The Pennsylvanian system includes a maximum thickness of 2,800 feet of blue and gray shales, limestones, and sandstones. The prominent limestones include the Foraker, Pawhuska, Oread, and the Oswego-Big lime group. The most prominent sandstones include the Hoover sand series, the Endicott sand series, and the Layton sand. The Tonkawa sand is represented only by a sandy shale zone over the top of the fold. Thin beds of red rock are found at the top of the Endicott sand zone and a short distance above the base of the Pennsylvanian.

The Mississippian system is represented by the Mississippi lime, with a maximum thickness of 300 feet. It varies from a gray to dark brown or black cherty limestone, with a variable thickness of residual chert at the top.

The Chattanooga shale, a black carbonaceous shale containing a considerable amount of iron pyrites, has in the past been referred to the Devonian system, but some recent workers are in-

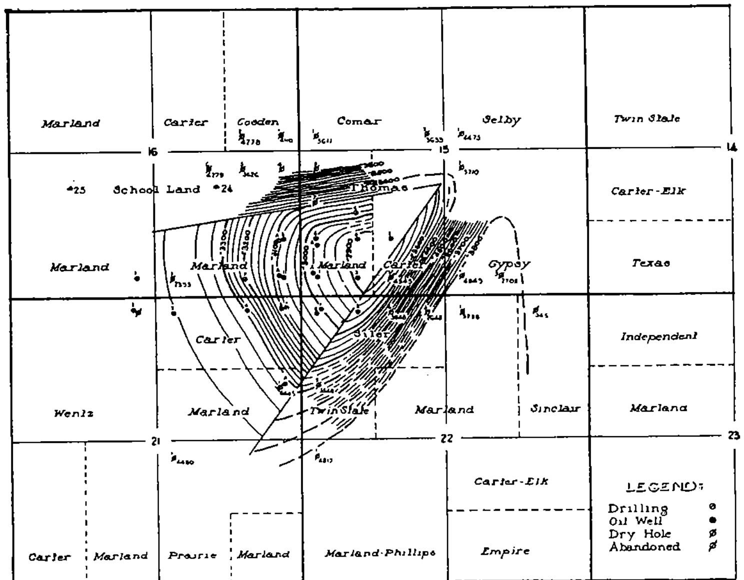


Figure 8—Structure map of Thomas field ("White lime" horizon).

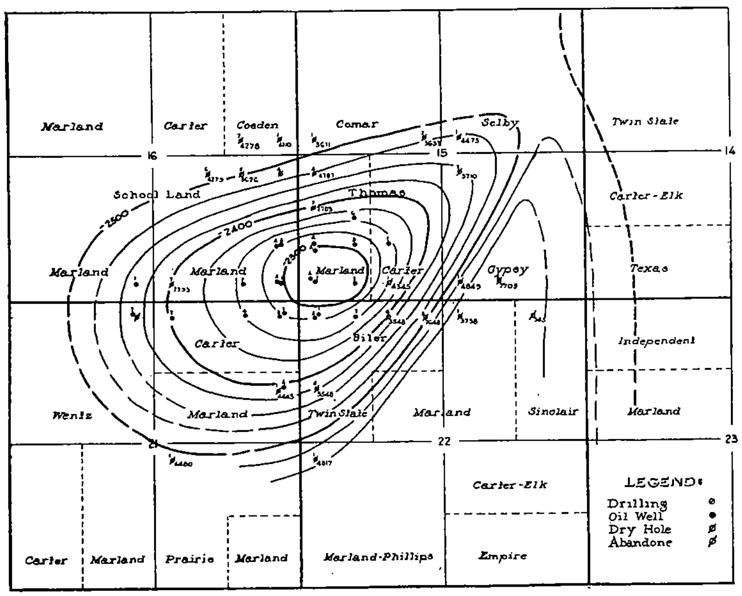


Figure 9—Structure map of Thomas field (Layton horizon).

clined to place it in the Mississippian. It has a uniform thickness of about 30 feet.

Rocks of strictly Ordovician age in this area include the "white lime" and the Simpson formation. As the name implies, the "white lime" is a white to putty-colored limestone about 15 feet thick, which is believed to be the equivalent of the upper part of the Viola limestone.

In the Tonkawa field the thickness of the Wilcox member is about 120 feet. The remainder of the Simpson section there consists of alternating beds of black and green shale and thinner beds of sandstone similar in character to the Wilcox sand.

Below the Simpson formation is an unknown thickness of the "Siliceous lime" of Cambro-Ordovician age.

STRUCTURE

The Thomas field lies on a major line of folding passing through the Blackwell, Otstot, Retta, and Garber fields. The structure and geologic history of all these fields are closely related. (See Figs. 8, 9, 10, and 11).

From the evidence now available it appears that the first local structural movement affecting this area came at the close of Mississippian time. As a result of this movement a wedge-shaped segment of the pre-Pennsylvanian rocks was elevated approximately 1,000 feet above the adjoining area. The structure developed by this movement is indicated on the structure map by contours drawn on the top of the "white lime" (Fig. 8).

During, and subsequent to the elevation of this wedge, erosion altered its topography by removing from its crest between 300 and 400 feet of sediments, including all the Mississippi lime, the Chattanooga shale, the "white lime" and part of the Wilcox sand, thus leaving an inlier of Wilcox sand exposed at the top and the truncated surfaces of the "white lime," Chattanooga shale, and Mississippi lime successively exposed on the flanks. Beds of residual chert, presumably resulting from the concentration of the silica originally present in the eroded portion of the Mississippi lime, accumulated on the slopes of the hill.

The original form of the hill was further modified by a reduction in the height of the fault scarps; that is, the areas immediately adjacent to and on the upthrown sides of the faults, being more exposed, were reduced more by erosion.

The two cross-sections, A-A and B-B (Figs. 10 and 11), show in vertical section the relation between the pre-Pennsylvanian structure and topography, and give an accurate impression of the amount of material removed by erosion.

Following this period of erosion the pre-Pennsylvanian hill was gradually submerged and eventually buried under several thousand feet of sedimentary rocks. For a time, however, the top of the hill formed an island in the Pennsylvanian sea. This is indicated by the fact that the first beds deposited on the flanks of the hill do not extend over its crest; and also by the fact that the crest of the hill contributed some material in the form of Wilcox sand grains and small fragments of green shale to the earliest Pennsylvanian bed, the shale between the red rock and the top of the Mississippi lime.

But even after this hill was completely buried its presence influenced the entire subsequent geologic history of the area. In fact, the structure of the younger rocks is simply a modified likeness of the topography of the buried hills. The degree of likeness decreases steadily upward: that is, the folding of the successive beds becomes less pronounced, the dips becoming more

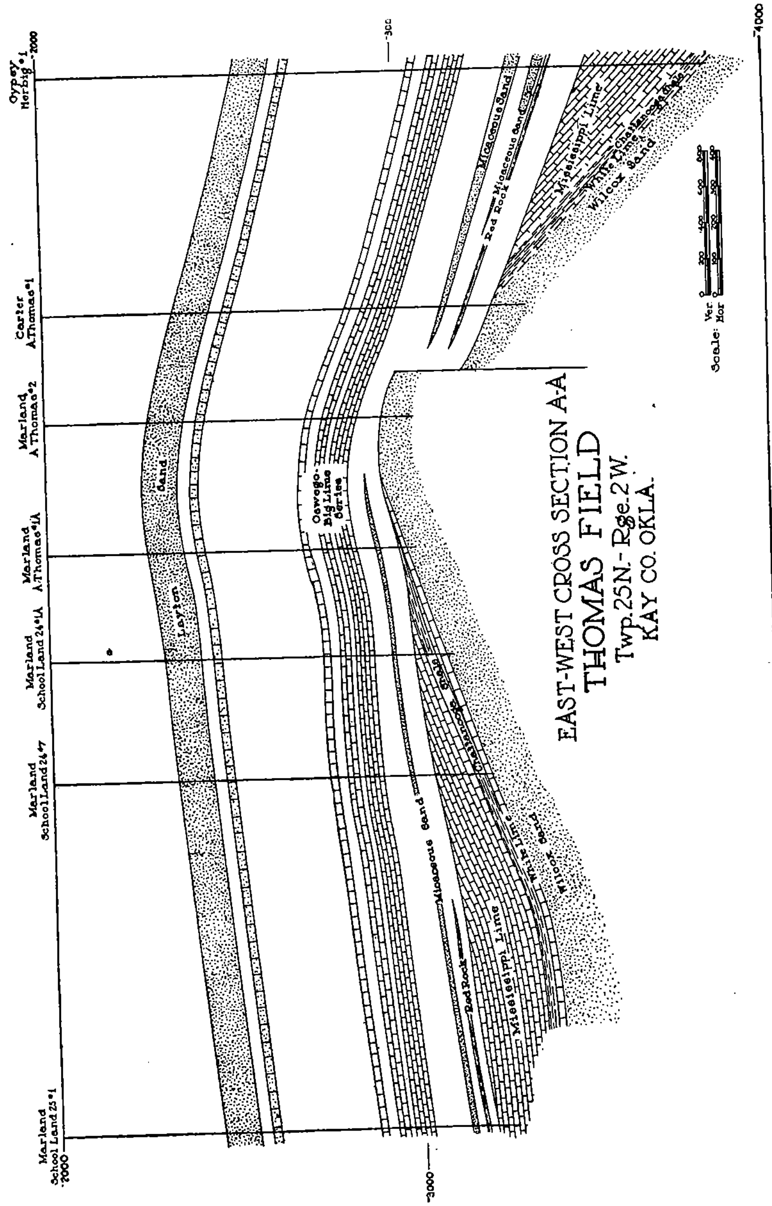


Figure 10—East-west cross-section, Thomas field.

and more gentle as the thickness of intervening strata increases. These features are illustrated in the accompanying maps, (Figs. 8 and 9), showing the structure of the Layton sands and the "white lime" horizons.

OTSTOT FIELD

The Otstot field is located just north of the center of T. 27 N., R. 1 W., just west of the town of Blackwell, Kay County.

STRUCTURE

The Otstot field lies on the general trend of folds, called the Blackwell Anticline in this report.

Production is obtained from a pre-Chattanooga terrace which has been dissected by streams of that age. This terrace is almost level on top, and the edge wells which define the field are found two to three hundred feet lower than those in the producing area. The Mississippi lime and the Chattanooga shale are not present on the top of this old topographic high, having been removed by the pre-Cherokee interval of erosion.

PRODUCTION

The defined producing area is about four square miles in extent. The wells on the highest part of the structure produce large quantities of gas, the average production of which is 50 million cubic feet. The oil producing wells are located principally on the northern and north-eastern edge of the field and produce from the same horizon from which the gas is obtained. Some of these wells when brought in produced gas, later making oil. Average production for the oil wells is 100 to 500 barrels. The shallowest production is found in the Stalnaker sand in a few wells on the eastern edge of the field. Average production from this sand is 100 to 200 barrels. An irregular sand found at 3,100 feet, which is a sandy phase in the upper part of the Oswego-Big lime series, produces in a few wells in sec. 16. Some of these wells have shown an initial production as high as 2,900 barrels but their decline was very rapid.

RETTA FIELD

The Retta field is located in secs. 1 and 12, T. 26 N., R. 2 W., Kay County.

HISTORY

The discovery well of this pool is the Hubbard No. 1, NW.¼ sec. 12, T. 26 N., R. 2 W. This well had no production in the Wilcox sand but found oil in the Siliceous lime at a depth of 2,760 feet, which is 150 feet below the top. This production is deeper in the Siliceous lime than in any other well in the district.

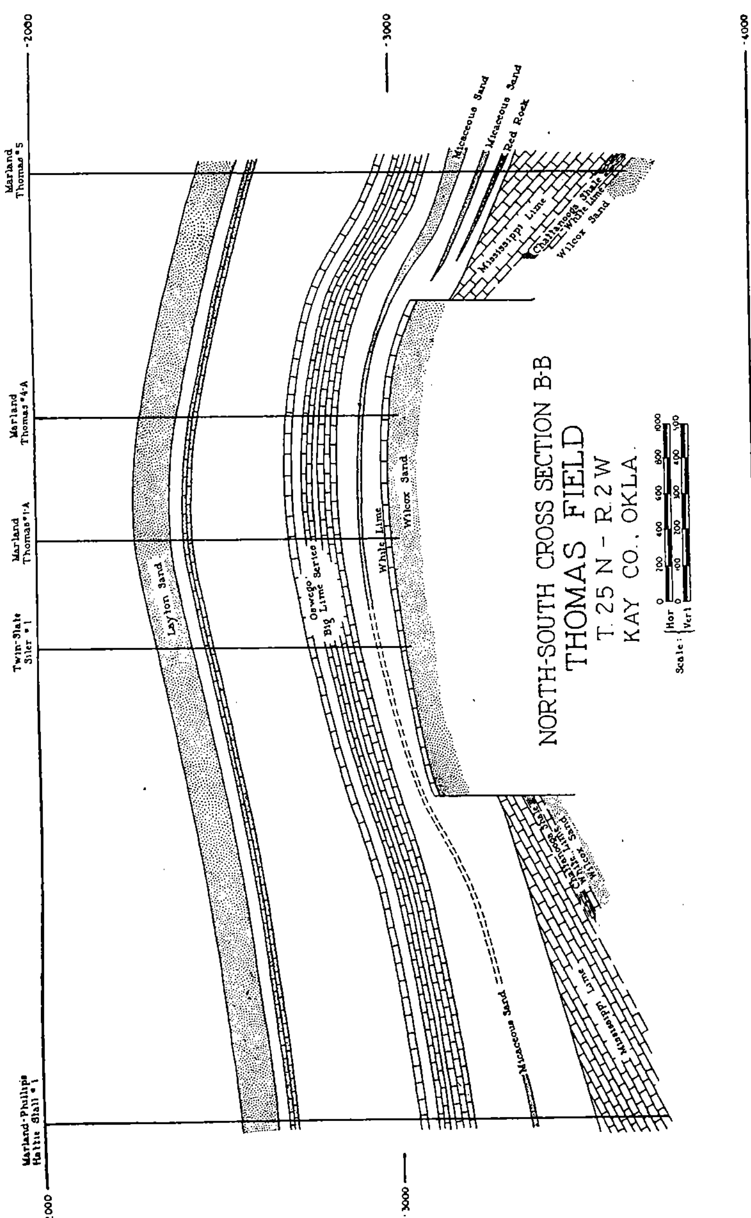


Figure 11—North-south cross-section, Thomas field.

STRUCTURE

The Retta structure is a small irregular, well defined dome, cut by a normal fault on its western side. This fault dips approximately 45° west, has 150 feet of displacement and is one of the few faults in this general region which is reflected in the Permian rocks on the surface. There is no evidence to check the presence of this fault in the Wilcox sand and deeper formations because of lack of drilling, but it is entirely probable that the fault extends through all of the sedimentary rocks to the granite below.

PRODUCTION

There are four producing horizons in the Retta field. The shallowest production is from the Stalnaker sand at an average depth of 2,500 feet. These wells produce mostly gas but some produce oil with an average production of 100 to 800 barrels. The wells decline rapidly, so that many of the Stalnaker sand wells are later deepened to the Layton horizon which is the next producing sand below the Stalnaker. The Layton is found, on an average, at a depth of 2,950 feet and produces 100 to 200 barrels. The Layton sand wells hold their production much better than the Stalnaker wells. The Wilcox sand is found at an average depth of 3,600 feet and makes from 300 to 1,300 barrel wells. The Siliceous lime at 3,700 feet has furnished a few small wells.

The first Wilcox well began producing in September, 1926, making about 600 barrels of oil. In January, 1927, eight wells in the Wilcox sand produced an aggregate of 4,000 barrels per day. The five wells in the Siliceous lime are all small producers and water trouble is general at this horizon. This field is not yet defined and at this date there are fifteen drilling wells, all of which are to be drilled to the Wilcox sand which is the important producing horizon.

VERNON FIELD

The Vernon pool is located in secs. 16 and 17, T. 29 N., R. 1 E., Kay County. The pool is just southwest of the shallow gas area in sec. 15, T. 35 S., R. 2 E., in Kansas which has been producing for several years.

STRUCTURE

The Vernon structure is a small dome lying on the Blackwell Anticline and is problably cut off from the Blackwell field structure by a small syncline or saddle.

PRODUCTION

The discovery wells produced gas at 2,000 feet which is equivalent to the Endicott horizon of the Tonkawa field. Later wells which averaged from 100 to 300 barrels produced from the Stalnaker sand at 2,300 feet. The chat at the top of the Mississippi lime (3,350 to 3,400 feet) produces 50 to 250 barrels.

BRAMAN FIELDS

NORTH BRAMAN

The north Braman field is located in sec. 21, T. 29 N., R. 1 W., in Kay County. The entire field covers approximately 600 acres with the deeper production confined to an area of about 80 acres.

The structure is a flat-topped hill which rises gradually from the east, is fairly level at the top, and dips steeply to the west. The highest part of the structure produces from the Siliceous lime with a maximum of 2,500 barrels, while to the east production is obtained from the Wilcox sand which has produced wells as big as 8,500 barrels. Shallow production is found in the Lower Hoover (1,900 feet) and the Upper Endicott (2,100 feet). The Hoover shale sands occur above the Oread lime (in the shale interval between it and the Pawhuska); whereas, according to some correlations the 1,900 foot sand lies above the Oread and the 2,100 foot sand below it in the Braman field, putting the latter in the Endicott zone. The initial production from these wells is about 1,800 barrels which decline to an average production of 175 to 500 barrels. These sands do not produce in the southern Braman area because they are practically absent there.

SOUTH BRAMAN

The South Braman pool is located in secs. 5 and 8, T. 28 N., R. 1 W., Kay County.

STRUCTURE

The South Braman structure is a sharp fold (200 feet of dip in one-fourth mile) on the lower horizons. This fold is probably faulted on the west in much the same way as the Retta structure. The Mississippi lime, Chattanooga shale and a part of the Wilcox sand are not present on the top of this fold.

PRODUCTION

The discovery well of this pool is located in the center of the south line of the SE.¼ SW.¼ sec. 5, very near (600 feet) the corporate limits of Braman. This well produced over 5,000 barrels of oil in the Stalnaker sand at 2,387 feet. The excitement caused by this discovery well resulted in 33 locations on the Braman townsite of which three were brought in as small producers. This feverish development has resulted in the loss of thousands of dollars and in much destruction of property in the town due to drilling activities. The Stalnaker sand (2,300 feet) and the Layton sand (2,800 feet) make wells with an average production of 100 to 5,000 barrels, while some have reached a maximum of 5,000 to 6,000 barrels. These sands are non-productive in the north Braman area. Most of the deep producers are from the Siliceous lime (3,300 to 3,400 feet) and are included within an area of about 80 acres.

There is some Wilcox production in both pools.

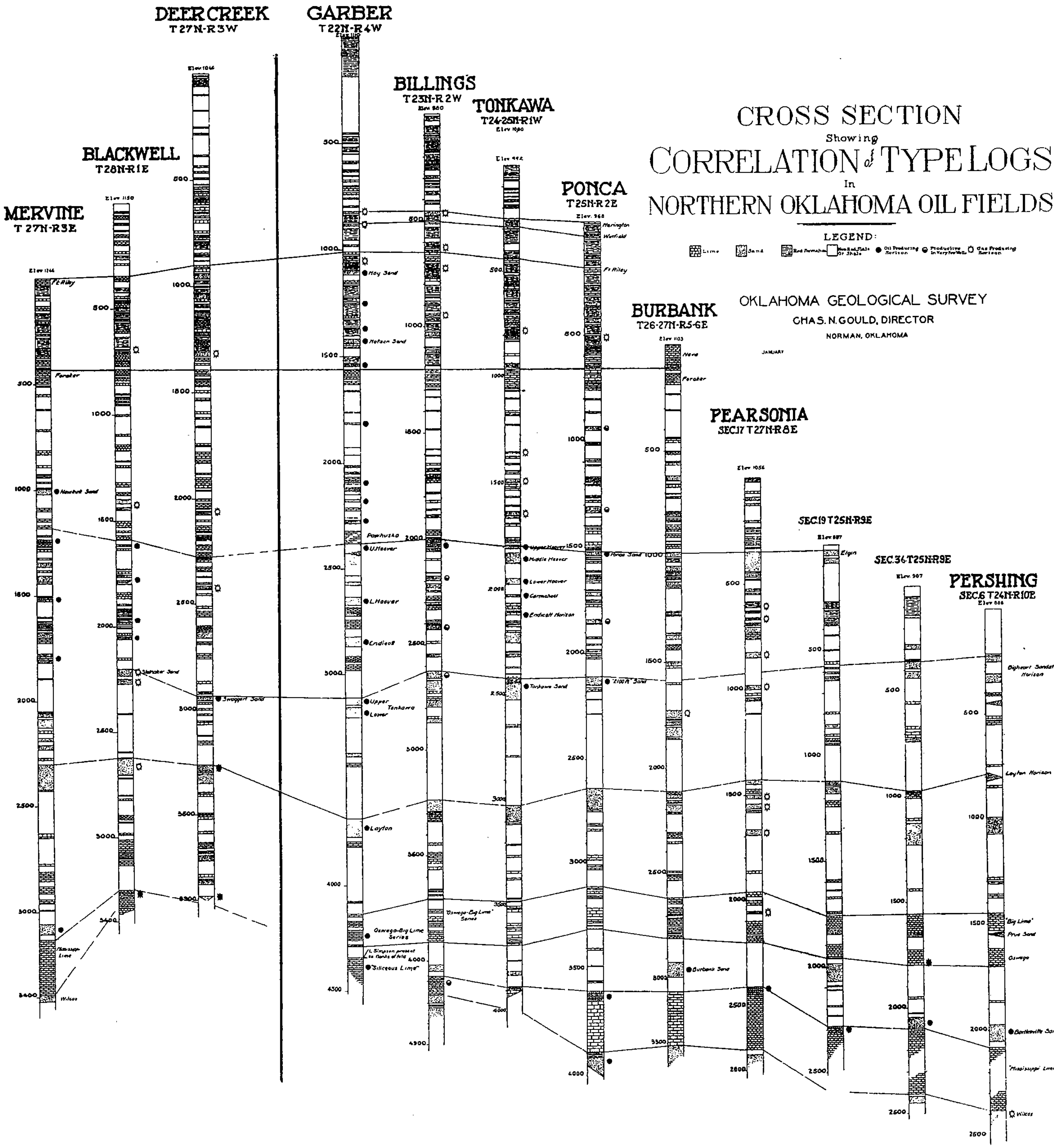
Correlation of producing sands with surface equivalents.

MERVINE	BLACKWELL	DEER CREEK	GARBER	BILLINGS	TONKAWA	PONCA	BURBANK	SURFACE EQUIVALENTS	
1246	**1150**	**1046**	**1110**	**980**	**1060**	**968**	**1103**	< **Surface elevations**	
Fort Riley	Wellington	Wellington	Garber	Wellington	Wellington	Herington	Neva-Foraker	Surface	
			(825)	(450)				Herington	
			(875)					Winfield	
			(1050)v	(625)^				Ft. Riley	
			Hoy (1100)	(725)				Matfield	
			Kisner (1250)v (1375)	(950)v				Crouse	
	(700)^	Hotson (?) (1300)^	Hotson (1425)^		Hotson (?) (725-825)	(500)^		Neva	
			(1550)^		(1350) (1500) (1650)			Foraker	
			(1810)			(900) (?)		Grayhorse	
	Newkirk (?) (1400)	Newkirk (?) (2000)	(2350)			(1300)		Bird Creek or Turkey Run (U.Pawhuska)	
U. Hoover (1200)	Hoover (1600) (1750)	L. Hoover (2400)	Hoover (2450)	Hoover (2000) (2200)	Hoover (1800) (1850) (1950)	Ponca (1500)		Elgin	Oread
Endicott (1500)			Endicott (2750)^	(2400)	Carmichael (2025) Endicott (2100)^	Endicott (1800)		U. Nelagoney	Wynona Four Mile
	(?) (1900) (2050)							Revard	Cochabee
Stalnaker (?) (1800)	Stalnaker (2200)	Swaggert (2900)	Tonkawa (3100)	Tonkawa (2650)	Tonkawa (2400)	"2100 foot"	(?) (1750)	Bigheart	
	Layton (2625)	Layton (3250)	Layton (3630)					Coffeyville (?)	
								Pawnee ("Big Lime")	
			Oswego (4180)					Ft. Scott (Oswego)	
Burbank (3100)^							Burbank (2960^	Bluejacket (Bartlesville)	
				"Miss. Lime" (4100)		"Miss. Lime" 3600		"Mississippi Lime" (Boone)	
	Wilcox (3300)	Wilcox (3900)	Burgen (4350)		Wilcox (4100)	Wilcox (3900)	Wilcox (3300)	Simpson	
			Siliceous Ls. (4400)					Arbuckle	

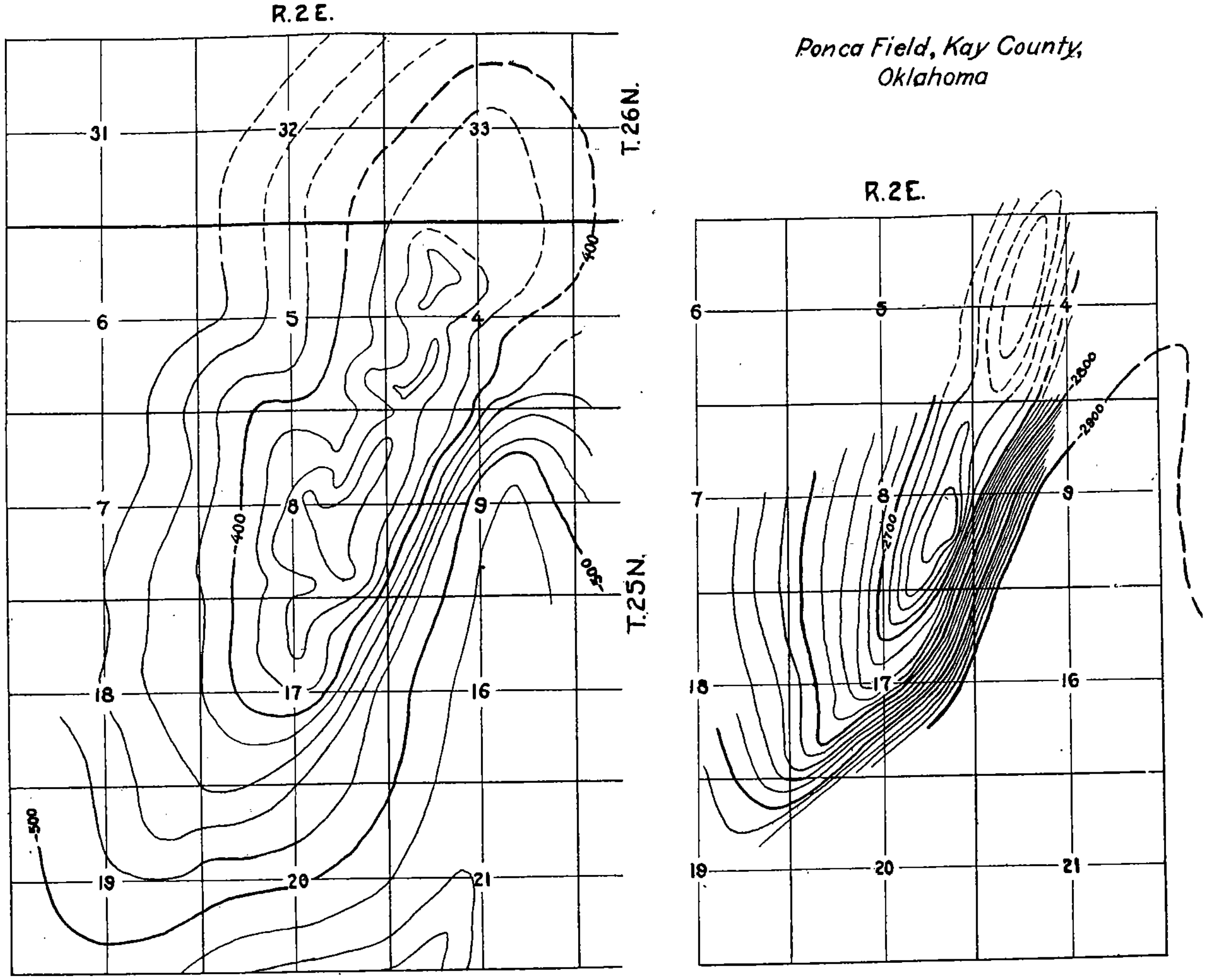
EXPLANATION

Numbers in parentheses (3250) show depth to top of sand below surface elevation.
v Lies above corresponding formation shown in last column.
v Lies below corresponding formation shown in last column.
(?) Sufficient data not available for definite correlation.

PLATE II



CROSS SECTION
Showing
CORRELATION of TYPE LOGS
In
NORTHERN OKLAHOMA OIL FIELDS
LEGEND:
OKLAHOMA GEOLOGICAL SURVEY
CHAS. N. GOULD, DIRECTOR
NORMAN, OKLAHOMA
DEER CREEK
T27N-R3W
GARBER
T22N-R4W
BILLINGS
T23N-R2W
TONKAWA
T24-25N-R1W
BLACKWELL
T28N-R1E
PONCA
T25N-R2E
MERVINE
T27N-R3E
BURBANK
T26-27N-R5-6E
PEARSONIA
SEC.17 T27N-R8E
SEC.19 T25N-R9E
SEC.34 T25N-R9E
PERSHING
SEC.6 T24N-R10E

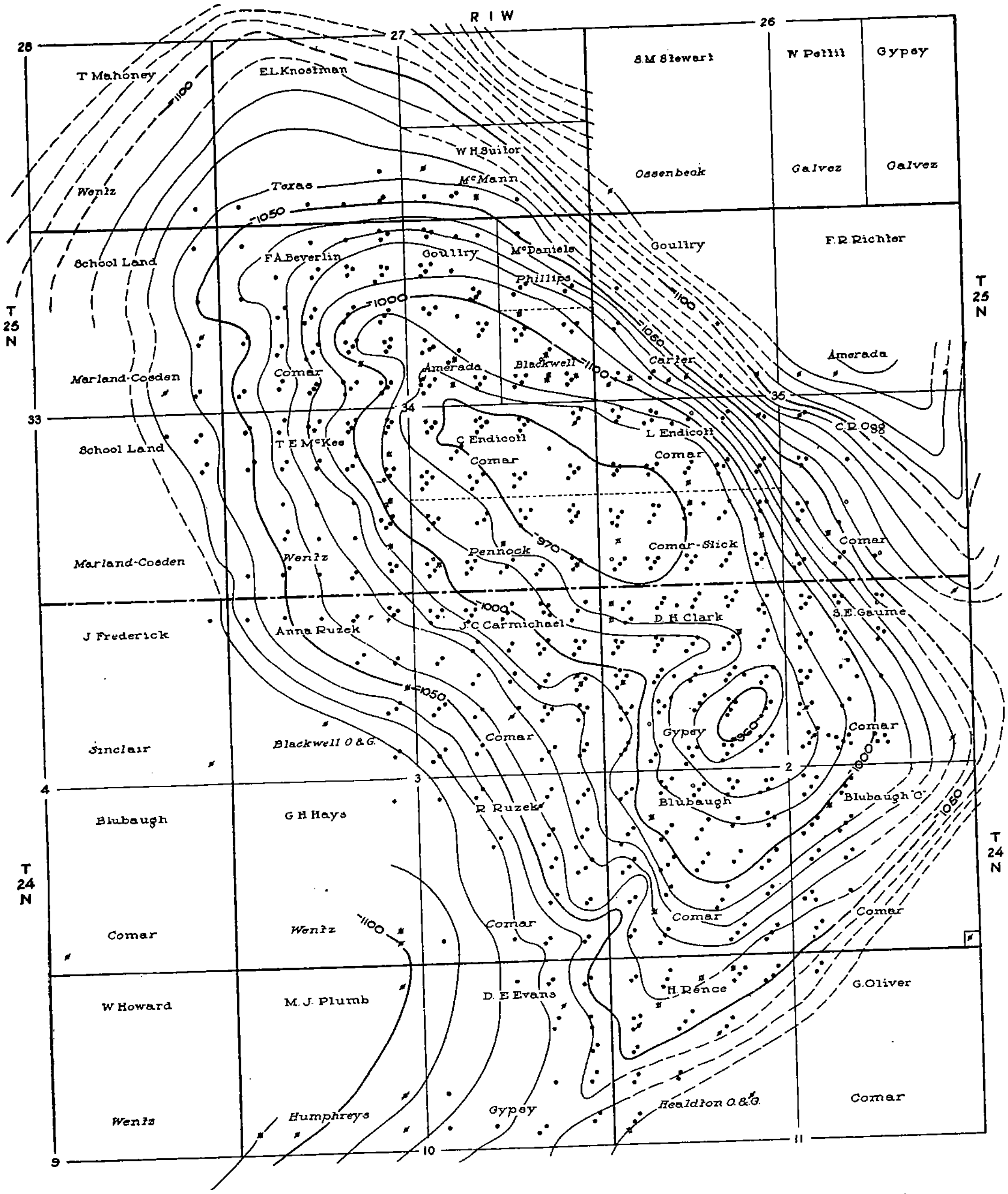


Contour Interval 20.'

A-Contours on 1,300' sand.

B-Contours on "Miss. Lime."

PLATE V



STRUCTURE MAP OF TONKAWA FIELD (LOWER HOOVER HORIZON)