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SUBSURFACE GEOLOGY AND OIL AND GAS RESOURCES OF OSAGE COUNTY, OKLAHOMA

PART 10. Burbank and South Burbank oil fields Townships 26 and 27 North, Range 5 East, and Townships 25 to 27 North, Range 6 East

BY

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FOREWORD

This report on the subsurface geology of Osage County, Okla., describes the structural features, the character of the oil- and gas-producing beds, and the localities where additional oil and gas may be found. It embodies a part of the results of a subsurface geologic investigation of the Osage Indian Reservation, which coincides in area with Osage County. The investigation was conducted by a field party of the Geological Survey of the United States Department of the Interior in 1934 to 1937 and involved the study of the records of about 17,000 wells that have been drilled in Osage County. Funds for the investigation were allotted to the Geological Survey by the Public Works Administration. The primary purpose of the examination was to obtain geologic data for use in the administration of the Indian lands. The results of the inquiry have shown that many localities in Osage County outside the present producing oil fields are worthy of prospecting for oil and gas and that additional oil and gas can be found also by exploring deeply buried beds in old producing fields.

All townships in Osage County that contain many wells are described; the information furnished by such townships is ample for drawing detailed subsurface structure-contour maps. The descriptions of several contiguous townships are combined in separate reports, which are issued as parts of a single bulletin. No edition of the consolidated volume will be published, but the several parts can be bound together if desired.

The subsurface investigation of Osage County was carried on mainly by L. E. Kennedy, W. R. Dillard, H. B. Goodrich, Charles T. Kirk, J. D. McClure, Otto Leatherock, Constance Leatherock, W. E. Shamblin, J. N. Conley, H. D. Jenkins, J. H. Hengst, G. D. Gibson, and N. W. Bass, geologists. The work of each geologist contributed more or less to the results of the investigation in each township. However, the investigations of the individual townships in Osage County were made mainly by various individuals of the group, and their names appear in the township descriptions. In addition to those whose names appear above, valuable assistance in the compilation of information was given by Lucile Linton, S. B. Thomas, R. C. Beckstrom, B. A. Lilienborg, J. G. Dwen, K. H. Johnson, J. G. Beaulieu, C. R. Viers, E. L. Hitt, Grace Clark, R. A. Payne, and J. C. Rollins.

Oil companies and individuals who contributed information are too numerous to acknowledge all by name. Special mention is made, however, of Laughlin-Simmons & Co. and the Indian Territory Illuminating Oil Co. for supplying most of the well elevations used in Osage County; of the Continental Oil Co., Tidal Oil Co., Sinclair Prairie Oil Co., Indian Territory Illuminating Oil Co., Phillips Petroleum Co., W. C. McBride, Inc., The Carter Oil Co., and others for supplying well logs, maps, cuttings, and cores of the producing sands in Osage County.

H. D. Miser, geologist in charge of the section of geology of fuels, supervised the work upon which this report is based. Appreciative acknowledgment is here made of many suggestions made by him during the progress of the investigation and during the preparation of the manuscript. Grateful acknowledgment is due the officers of the Osage Indian Agency at Pawhuska and the late John M. Alden, and others in the Tulsa office of the Geological Survey for cooperation and assistance; also Hale B. Soyster and H. I. Smith, of the Geological Survey, for sponsorship and interest in the investigation.

N. W. Bass.

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By N. W. BASS, H. B. GOODRICH, and W. R. DILLARD

ABSTRACT

The Burbank and South Burbank oil fields, whose subsurface geology and oil and gas resources are described in this report, lie in Tps. 26 and 27 N., R. 5 E., and Tps. 25 to 27 N., R. 6 E., Oklahoma. The area covered by these fields is mainly in west-central Osage County but includes also a small part of Kay County. Fairfax is just south of its south boundary, and Kaw is just west of its west boundary. Shidler is within the area. The oil in these fields occurs mainly in the Burbank sand at depths ranging from about 2,700 to 3,000 feet. Three other zones have yielded small amounts of oil in a few wells, and still two others have yielded gas in a few wells.

The regional dip of the rocks in the Burbank and South Burbank fields, as measured on the top of the Oswego lime, is westward at an average rate of 35 feet to the mile. The dip is relatively uniform, being interrupted only by a few domes of relatively small structural relief. The domes have no particular significance, because the oil in the Burbank sand occurs independently of the attitude of the rocks. The oil pools occur in lens-shaped sand bodies that thin out in all directions. The sand bodies represent a series of beach deposits that were formed on the western shore of the sea during Pennsylvanian time.

The results of the investigation suggest that oil-bearing sand bodies similar to those in the Burbank and South Burbank fields are probably present to the south of these fields. These postulated sand bodies probably lie in two or more belts that represent southward extensions of the sand bodies in the Burbank and South Burbank fields.

INTRODUCTION

The subsurface geologic features of the Burbank and South Burbank oil fields, in Tps. 26 and 27 N., R. 5 E., and Tps. 25 to 27 N. R. 6 E., Osage and Kay Counties, Okla., are described in this report, which is the tenth in a series of reports covering parts of Osage County. The structure of the buried rocks, the location of producing and abandoned oil and gas wells and dry holes, and the ownership of leases are shown on the map listed as plate 10. The oil- and gas-bearing beds in producing wells and abandoned producers and the deepest beds penetrated in dry holes are shown on this map by colors on the black well symbols. Wells that produced oil or gas from shallow depths and were drilled to test older rocks are indicated by special symbols. Plate 10 includes also a small key map showing the location of the townships covered by this report. Other maps include figure 2, showing the reservoir sand body of the Burbank field during an early stage of its development and a hypothetical oil-bearing sand body south of the field; figure 3, showing the sand bodies of the Burbank and South Burbank fields and hypothetical sand bodies south of these fields; plate 11, showing the thickness of the Burbank sand in the Burbank and South Burbank fields as recorded in drillers' logs; and plate 12, showing the initial daily yields of the wells in these two fields.

All the oil- or gas-producing beds in Tps. 26 and 27 N., R. 5 E., and Tps. 25 to 27 N., R. 6 E., are described briefly; these beds and all others that have been penetrated by the drill are shown graphically in a generalized columnar section on plate 10. The beds that produce oil or gas are indicated on the columnar section by colors that correspond to the colors on the well symbols on the structure-contour map. The oil- and gas-producing beds in each of the five townships are listed also in the following table.

Oil- or gas-producing beds in Tps. 26 and 27 N., R. 5 E., and Tps. 25 to 27 N., R. 6 E., Osage and Kay Counties, Okla.

T. 26 N., R. 5 E.	T. 27 N., R. 5 E.	T. 25 N., R. 6 E.	T. 26 N., R. 6 E.	T. 27 N., R. 6 E.
	Revard and Bigheart sand zone.		Revard and Bigheart sand zone.	
Okesa, Torpedo and Clem Creek sand zone.				
		Skinner sand.		
Burbank sand.	Burbank sand.	Burbank sand.	Burbank sand.	Burbank sand.
	Mississippi lime.	Mississippi lime.	Mississippi lime.	
			Simpson formation and Siliceous lime.	

The exposed rocks in the five townships belong in the upper part of the Pennsylvanian series and include many ledge-forming beds of limestone and a few thick beds of sandstone. Their distribution is shown on the State geologic map by Miser.[1]

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[1] Miser, H. D., Geologic map of Oklahoma, U. S. Geol. Survey, 1926.

The stratigraphy and structure of the rocks in T. 27 N., R. 6 E., in the Osage County part of T. 27 N., R. 5 E., and in an area lying along the north boundary of T. 26 N., Rs. 5 and 6 E., are described by Heald;[2] and the structure of the rocks in T. 25 N., R. 6 E., and in all of T. 26 N., Rs. 5 and 6 E., except the aforementioned area along the north boundary, is described by Bowen.[3]

The subsurface investigation of the Burbank field was conducted by several geologists of the Geological Survey, principally in 1936 and 1938. The parts of plates 10 and 11 that represent the Burbank field were prepared mainly by H. B. Goodrich, and the parts that represent the South Burbank field were prepared mainly by W. R. Dillard, who also compiled the data on the occurrence of water in the reservoir sand. Plate 12 and figures 2 and 3 were prepared by N. W. Bass. Most of the data on oil production were compiled by the Phillips Petroleum Co., and the remainder by Ona Lee McKeen from records on file at the Osage Indian Agency. The drafting of the maps was done by Samuel B. Thomas.

OIL- AND GAS-PRODUCING BEDS

Oil or gas has been produced in Tps. 26 and 27 N., R. 5 E., and Tps. 25 to 27 N., R. 6 E., from six zones, ranging from the lower part of the Simpson formation of Ordovician age, or possibly the uppermost part of the Siliceous lime, of Cambrian and Ordovician age, to the Revard and Bigheart sand zone, of Pennsylvanian age. Depths to the oil- or gas-bearing rocks range from about 1,400 to 3,200 feet. Of about 2,500 producing wells, all except about a dozen produced from the Burbank sand at depths of about 2,700 to 3,000 feet. The Mississippi lime yielded a small amount of oil in a few wells that are widely separated, and the Simpson formation yielded oil in three wells, all of which are in a single locality in T. 26 N., R. 6 E. The Skinner sand yielded oil in one well in sec. 26, T. 25 N., R. 6 E. The Okesa, Torpedo, and Clem Creek sand zone (Suitcase sands) yielded gas in a few wells in sec. 1, T. 26 N., R. 5 E. The Revard and Bigheart sand zone yielded gas for a time in two wells—one in sec. 1, T. 26 N., R. 6 E., and the other in sec. 4, T. 27 N., R. 5 E. Brief descriptions of the oil- and gas-producing beds, from the oldest to the youngest, follow.

SILICEOUS LIME AND SIMPSON FORMATION

A show of gas from the uppermost beds of the Siliceous lime was reported in only one well, but these beds have not been tested on the

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[2] Heald, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey Bull. 641, pp. 17–47, 1916.

[3] Bowen, C. F., in White, David, and others, Structure and oil and gas resources of the Osage Reservation, Okla.: U. S. Geol. Survey Bull. 686, pp. 137–148, 1922.

crests of a few domes. The Siliceous lime consists mainly of limestone and dolomite, some beds of which contain chert. Three deep wells in the Burbank field, two of which reached the pre-Cambrian basement rocks, show the total thickness of the Siliceous lime to be about 1,000 feet. In the central part of the area its top lies at a depth of about 3,300 feet. The lower part of the lime is probably of Cambrian age and the upper part of Ordovician age.

The Simpson formation unconformably overlies the Siliceous lime. Its upper part, known as the Tyner formation, consists of interbedded green shale, sandy shale, and sandstone, and its lower part, believed by White[4] to represent the Burgen sandstone, consists almost wholly of sandstone. The thickness of the Simpson as a whole ranges from 100 to 140 feet. Its lower sandstone member has yielded oil in three wells in sec. 9, T. 26 N., R. 6 E.

MISSISSIPPI LIME

The Mississippi lime, which is about 325 feet thick, is composed mainly of limestone but includes also some chert and cherty limestone. Weathered chert occupies the topmost 20 to 50 feet in most localities. Of about 100 wells, widely distributed through the area, that have tested the Mississippi lime, only 4 or 5 have produced oil. One of these, well 6 in the NE¼ sec. 15, T. 25 N., R. 6 E., has produced more than the others.

BURBANK SAND

Nearly all the oil produced by these five townships has come from the Burbank sand. In most localities this sand lies near the base of the Cherokee shale and is separated from the underlying Mississippi lime by a thin bed of black to dark-gray shale, but in some it appears to be in contact with the topmost chert beds of the lime. The Burbank sand occurs as broad lenses, with a maximum thickness of a little more than 100 feet, that pinch out into shale beds. (See pl. 11.) Not uncommonly shale and sandy shale partings occur within the sand body. Such partings are reported by operators to increase in number toward the margins of the sand bodies, particularly the western margins. The eastern margins of the sand lenses are sharply defined along a smoothly flowing line that coincides with the boundaries of the oil pools; the western margins are more irregular. The sand bodies are marked by narrow belts of thick sand that trend approximately parallel to the eastern margins of the pools but swing westward in the northern part of the Burbank pool on a line approximately parallel to the north margin of that pool.

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[4] White, L. H., Subsurface distribution and correlation of the pre-Chattanooga ("Wilcox" sand) series of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 40, vol. 1, pp. 29–30, 1928.

The Burbank sand is composed mainly of angular to subangular quartz grains that range in size from very fine to medium, but minor amounts of mica and traces of other minerals are present also. The shaly parts of the sand commonly contain minute concretions of siderite. The Burbank sand in general is firmly bonded; its uppermost part is mainly a hard siltstone, below which in most localities is sand, the uppermost smaller part of which yields gas and the remainder, or main part, yields oil. The thickness of the oil-bearing part of the Burbank ranges from less than 10 to more than 60 feet, the average being between 40 and 50 feet.

SKINNER SAND

A bed of sand that is only 10 to 25 feet thick is recorded in the logs of a few wells about 30 feet above the Burbank sand, at about the stratigraphic position of the Skinner sand. This sand yields oil in one well in sec. 26, T. 25 N., R. 6 E.

OKESA, TORPEDO, AND CLEM CREEK SAND ZONE

A sequence of sandstone, shale, and limestone about 175 feet thick, here tentatively referred to as the Okesa, Torpedo, and Clem Creek sand zone, occurs near the middle of the Ochelata formation. It lies at a depth of about 1,700 feet and includes the Suitcase sands of this region. In the western part of the Burbank field, beginning about a mile west of Shidler, thick lenticular beds of sandstone make up the larger part of this zone, but in the northern part of the field these sandstone beds lie somewhat lower in the Ochelata formation than this zone. As the sand zone extends eastward from the western part of the Burbank field, it changes, and thick beds of limestone predominate in places, and still farther east the zone is occupied by shale associated with a few beds of limestone but with little or no sandstone. Shale and a few beds of limestone occupy the position of the zone in the South Burbank field also. A bed of sandstone near the middle of the zone yielded gas for a time in a few wells on a dome in the NE¼ sec. 1, T. 26 N., R. 5 E.

The Okesa, Torpedo, and Clem Creek sand zone yields much water in most wells in the Burbank field.

REVARD AND BIGHEART SAND ZONE

A sequence of sandstone, limestone, shale, and a small amount of red rock lies at a depth of about 1,400 feet. It includes the Revard and Bigheart sand zone and is tentatively assigned to the lowermost part of the Nelagoney formation. Beds of sandstone in this sequence about 50 feet above its base yielded gas for a time in well

G-1 in the SE¼ sec. 1, T. 26 N., R. 6 E., and beds of sandstone near the same horizon yielded gas in well 9 in the NE¼ sec. 4, T. 27 N., R. 5 E.

STRUCTURE

The regional dip of the rocks in the Burbank and South Burbank fields is westward at the rate of about 35 feet to the mile as measured on the top of the Oswego lime. The westward dip is interrupted by many irregularly spaced folds of low relief, prominent among which are the dome in sec. 9, T. 26 N., R. 6 E., and a complex dome with several crests near the corner common to Tps. 26 and 27 N., Rs. 5 and 6 E. These two domes are clearly defined by the attitude of the exposed rocks as well as by that of the buried rocks. The buried rocks are more steeply folded than the exposed rocks—a structural feature common in the region.

In the Burbank and South Burbank fields the altitude of the Oswego lime is highest on the crest of the dome in the NW¼ sec. 9, T. 26 N., R. 6 E., where it is 1,460 feet below sea level; it is lowest on the western margin of the Burbank field, where in a few places the top of the lime is 220 feet lower than on the dome mentioned.

The structure contours shown on plate 10 are drawn at intervals of 10 feet on the top of the Oswego lime from data recorded in drillers' logs. The top of the Oswego lime is believed to be less undulating than as shown on plate 10, for small errors probably affect the measurements of the depths to the top of the lime, particularly in the Burbank field, and such errors have doubtless led to some misplacement in the position of the contours. Contour lines that encircle a single well are particularly questionable.

Several structural basins and synclines occur in the Oswego lime along the northeastern margins of the sand bodies of the main Burbank field and the Stanley stringer and along the eastern margin of the sand body of the South Burbank field. Some of these basins and synclines are in secs. 6, 7, 27, and 34, T. 27 N., R. 6 E., secs. 2, 11, 14, and 35, T. 26 N., R. 6 E., and secs. 2, 11, 15, and 22, T. 25 N., R. 6 E. They are not reflected in the exposed rocks,[5] as are most structural features of the Oswego lime in other parts of Osage County. This fact suggests that the folds of which these depressions are a part were not formed in the same way as were the other folds in Osage County. Their alinement with the northeastern and eastern margins of the lenticular bodies of Burbank sand and their gradual flattening out in the successively higher rock layers suggest that they may have

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[5] Heald, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey Bull. 641, pl. 2, 1916. Bowen, C. F., in White, David, and others, Structure and oil and gas resources of the Osage Reservation, Okla.: U. S. Geol. Survey Bull. 686, pl. 23, 1922.

been formed by the compaction of the sediments over these steeply sloping margins, for the Burbank sand lenses underwent less compaction than the adjoining column of shale immeditely east of them.[6]

The sand bodies reach almost their maximum thickness in narrow belts near their eastern margins and pinch out into shale rather abruptly within a distance of a few hundred yards east of these belts. Shale beds immediately east of the sand bodies underlie many of the structural depressions.

RELATION OF OIL AND GAS TO STRUCTURE

Although the finding of domes in the exposed rocks led to the discovery of the Burbank field, the development of the field has shown that domes occupy only small parts of the field. Wells far from the crests of the domes and in localities where the producing sand is much lower structurally than on the domes have much larger yields of oil than wells near the crests. For example, in the early-developed parts of the producing area, the Oswego lime is more than 100 feet lower structurally than it is on the crest of the dome in the NE¼ sec. 1, T. 26 N., R. 5 E., and 200 feet lower than it is on the crest of the dome in sec. 9, T. 26 N., R. 6 E. After wells had been drilled in many square miles of the field it was realized that the Burbank oil pool occupies a very large area that contains many small domes, anticlines, and structural basins, none of which have a bearing on the occurrence of the oil.

As early as two years after the initial discovery of the Burbank pool many geologists recognized the predominant importance of the character and thickness of the reservoir sand in controlling the accumulation of oil. The field then contained 256 producing wells and 1 dry hole and occupied a belt about 2 miles wide extending from the SE¼SE¼ sec. 25, T. 27 N., R. 5 E., southeastward to the NW¼NW¼ sec. 15, T. 26 N., R. 6 E.[7]

The wells with large initial daily yields lie in narrow belts that extend through the field in broad sweeping curves but bear no relation to the attitude of the beds. (See pl. 12.) Just as the wells in these belts have larger yields than the other wells, so the belts have larger yields than other areas. These noteworthy yields are believed to come from the middle highly permeable parts of the many overlapping sand bars that collectively form the reservoir sand bodies. The belts of highly permeable sand and the intervening belts of less permeable sand originated during the deposition of

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[6] Hedberg, H. D., The effect of gravitational compaction on the structure of sedimentary rocks: Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 11, p. 1063, 1926.

[7] Wagner, Paul, Burbank wells to be long-lived; make 30 percent of initial production: Nat. Petroleum News, pp. 58, 60, May 10, 1922.

the sand by the waves and currents that washed the western shore of the sea that existed during Pennsylvanian time.

The only oil thus far discovered in Ordovician rocks occurs on the dome in sec. 9, T. 26 N., R. 6 E., where three wells have yielded small amounts of oil from the Simpson formation. It is probable that the oil and gas pools in these beds are confined to domes and anticlines, as in other parts of Osage County.[8] The data are too meager to determine the relation of the structure to the oil found in a few places in the Mississippi lime. The principal gas-bearing area in the Okesa, Torpedo, and Clem Creek sand zone is on the dome in sec. 1, T. 26 N., R. 5 E. The relation of the gas in the Revard and Bigheart sand zone to the structure of the rocks is obscure, as gas was produced from this zone in only two wells—one in the NE¼-SE¼ sec. 1, T. 26 N., R. 6 E., several miles east of the Burbank field, and the other in the NE¼ sec. 4, T. 27 N., R. 5 E.

BURBANK FIELD

The Burbank field was discovered in May 1920, by the Marland Oil Co.'s well 1 in the SE¼NE¼ sec. 36, T. 27 N., R. 5 E. This well is on a dome that had been favorably recommended for testing by the Geological Survey.[9] In September 1920 two wells were completed by the Carter Oil Co. on a dome in sec. 9, T. 26 N., R. 6 E.[10] Development of the field proceeded rapidly during the next few years, and by the end of 1924 about three-fourths of the wells in the main part of the field had been drilled. The Stanley stringer, a long prong that lies on the eastern margin of the field, was discovered in 1926 by the Kewanee Oil & Gas Co.'s well 1 in the NE¼ sec. 34, T. 27 N., R. 6 E. The narrow producing belt of the stringer was developed mainly in 1927 and 1928, but the southeast end of the belt has not yet been defined.

The initial daily yields of wells in the Burbank field ranged from 10 to 8,000 barrels. The oil was accompanied by much gas,[11] and most of the wells flowed violently,[12] regardless of whether they were in parts of the field in which the rocks are structurally low or in parts in which the rocks are structurally high. The original pressure in much of the field was about 800 pounds to the square inch,[13] and according to Sands[14] the lessening of the gas pressure on one lease

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[8] See preceding chapters of this bulletin.

[9] Heald, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: U. S. Geol. Survey, Bull. 641, pp. 36–37, 1916.

[10] Bowen, C. F., in White, David, and others, Structure and oil and gas resources of the Osage Reservation, Okla.: U. S. Geol. Survey, Bull. 686, pp. 145–146, 1922.

[11] Sands, J. M., Burbank field, Osage County, Okla.: Am. Assoc. Petroleum Geologists Bull., vol. 8, no. 5, p. 588, 1924.

[12] Idem, p. 589.

[13] Idem., p. 591.

[14] Idem., p. 589.

had very little effect on the pressure on a lease half a mile away. Pressure was dissipated slowly, therefore, in spite of the fact that the wells produced at their maximum capacities.

The Burbank sand yields little or no water in the greater part of the Burbank and South Burbank fields. It yields water, however, in some wells in the northwestern part of the Burbank field, near the western margin of that field, and in some wells in the southwestern part of the South Burbank field. Also, water was found in the sand by prospect holes west of the fields. In the northwestern part of the Burbank field the amount of water produced in most wells declined as the rate of oil production declined. The water, therefore, is not under a strong hydrostatic head and does not occupy the sand body to its full thickness; thus the presence of water in the sand does not indicate that it marks the western limit of the oil pool, as has been assumed by some.

The occurrence of water at several different altitudes, and in several small areas that apparently are separated by other areas essentially barren of water, indicates that the water in the Burbank sand occurs in isolated patches or in lenses that lie entirely within the sand body. Such occurrences are shown in not less than six wells in T. 27 N., R. 5 E., along the western margin of the Burbank pool, at altitudes ranging from 1,884 to 1,900 feet below sea level. In a belt about three-quarters of a mile northeast of the margin, however, many wells were drilled into sand that is lower in altitude than the water-bearing sand farther west, but these wells did not encounter water. For example, water was found at an altitude of 1,889 feet below sea level in well 7 in the SE¼SW¼NW¼ sec. 15, T. 27 N., R. 5 E., and at an altitude of 1,892 feet below sea level in well 1 in the SE¼SW¼NE¼ sec. 16, but several wells in the E½ sec. 15 penetrated sand that lies from 1,920 to 1,930 feet below sea level and failed to encounter water. Well 10 in the SE¼ sec. 22, T. 27 N., R. 5 E., encountered water at an altitude of 1,896 feet below sea level, and well 1 in the northeast corner of sec. 27 encountered water at an altitude of 1,900 feet below sea level. About a mile east of these two wells, a group of several wells were drilled through sand that lies from 1,950 to 1,970 feet below sea level, and only three of the group produced water. Of these three wells, water was encountered in one at an altitude of 1,925 feet below sea level and in the other two at altitudes ranging from 1,945 to 1,951 feet below sea level.

The production peak of the Burbank field was reached in July 1923. During that month the average daily production was 88,950 barrels and a total of 1,020 wells were producing oil. By March 1, 1925, four years and nine months after the date of discovery of the field, a total of 97,429,751 barrels had been produced,[15] which made the Burbank field the largest producer in Oklahoma up to that date, with the exception of the Cushing field. By the end of 1938 a total of almost 200,000,000 barrels had been produced from the Burbank field; 80 percent of which came from the Osage County part of it. The field contains about 2,200 oil wells; the total oil-producing area is estimated to be 22,270 acres; and the average yield to the acre from its discovery to the end of 1938 was about 9,000 barrels. Parts of the pool are now being repressured with gas, and in 1939 a total of about 15,000,000 cubic feet of gas a day was being injected into the reservoir. The oil ranges in gravity from 38 to 40 degrees and is particularly valuable in the manufacture of high-grade lubricants.

All except a small part of the oil produced from the Burbank pool has come from the Burbank sand, which lies at depths ranging from about 2,700 to 3,000 feet. The Simpson formation yielded a small amount of oil in three wells in sec. 9, T. 26 N., R. 6 E., and the Mississippi lime yielded oil in a few wells. Gas was produced for a time from the Okesa, Torpedo and Clem Creek sand zone (Suitcase sand) in a few wells and from the Revard and Bigheart sand zone in two wells. The deepest well of the field, in the SE¼ sec. 11, T. 27 N., R. 5 E., reached a depth of 4,610 feet, where it was stopped in granite. A well in the NW¼ sec. 9, T. 26 N., R. 6 E., also reached granite at a depth of 4,230 feet.

The total amount of oil produced to the end of 1938, the bonuses paid for leasing the oil rights from the Osage Tribe, and the dates on which leases were sold at auction are shown, by tracts, in the following table, which was compiled in part by the Phillips Petroleum Co. and in part by Ona Lee McKeen from records on file at the Osage Indian Agency. Most leases sold were for tracts of 160 acres each. A bonus of at least $1,000,000 each was paid, at the sales of the leases, for 21 tracts, and for 8 of these a bonus in excess of $1,500,000 each was paid. The largest bonus for a single lease, $1,990,000, was paid in 1924 by the Midland Oil Co. for the tract covering the NW¼ sec. 14, T. 27 N., R. 5 E. This tract with two others in sec. 14 brought a combined bonus of $5,735,000, which is an average of $11,948 to the acre. A total of 2,354,737 barrels of oil had been produced from the three tracts by the end of 1938. On the other hand, a total of 4,939,778 barrels had been produced from the four tracts that comprise sec. 5, T. 26 N., R. 6 E., but the total bonus paid for leases on these tracts was only $2,900.

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[15] Oil Trade Journal, vol. 16, p. 42, April 1925.

Oil produced in the Burbank field

Tract	Bonus paid for lease	Date of sale of lease	Production to end of 1938 (barrels)	Tract	Bonus paid for lease	Date of sale of lease	Production to end of 1938 (barrels)
T. 26 N., R. 5 E.							
NE¼ sec. 1	$5,800	Nov. 9, 1918	896,449	NE¼ sec. 2	$410,000	June 28, 1922	434,921
NW¼ sec. 1	3,000	Nov. 9, 1918	1,127,809	NE¼ sec. 12	325,000	Dec. 12, 1921	252,746
SW¼ sec. 1	3,100	Nov. 9, 1918	581,023	NW¼ sec. 12	500,000	June 28, 1922	5,508
SE¼ sec. 1	5,200	Nov. 9, 1918	1,756,267				
T. 27 N., R. 5 E.							
SW¼ sec. 1	$710,000	Mar. 18, 1926	1,046,552	SE¼ sec. 15	$1,325,000	Apr. 5, 1923	1,764,040
SE¼ sec. 1	178,000	Sept. 30, 1926	440,212	NE¼ sec. 22	1,025,000	Apr. 5, 1923	3,509,596
NE¼ sec. 2	366,000	Mar. 18, 1926	257,552	SE¼ sec. 22	670,000	Apr. 5, 1923	1,018,106
NW¼ sec. 2	68,000	Mar. 18, 1926	24,926	NE¼ sec. 23	1,195,000	Apr. 5, 1923	2,085,135
SW¼ sec. 2	10,500	Dec. 18, 1924	166,191	NW¼ sec. 23	1,005,000	Apr. 5, 1923	2,640,030
SE¼ sec. 2	6,000	Mar. 18, 1925	1,260,831	SW¼ sec. 23	740,000	Apr. 5, 1923	1,836,593
NE¼ sec. 3	6,500	Mar. 18, 1926	24,926	SE¼ sec. 23	1,101,000	Jan. 18, 1923	1,478,867
SE¼ sec. 3	151,000	Mar. 19, 1924	158,380	NE¼ sec. 24	1,245,000	Jan. 18, 1923	2,362,932
NE¼ sec. 10	33,000	June 28, 1922	1,653,789	NW¼ sec. 24	1,310,000	Jan. 18, 1923	3,578,304
SE¼ sec. 10	41,000	June 28, 1922	3,366,355	SW¼ sec. 24	1,005,000	June 28, 1922	2,288,390
NE¼ sec. 11	335,000	Dec. 18, 1924	1,576,136	SE¼ sec. 24	1,600,000	June 28, 1922	2,521,849
NW¼ sec. 11	310,000	June 30, 1924	1,845,901	NE¼ sec. 25	1,335,000	Mar. 2, 1922	1,065,006
SW¼ sec. 11	1,765,000	Mar. 19, 1924	2,140,975	NW¼ sec. 25	1,160,000	Mar. 2, 1922	1,076,861
SE¼ sec. 11	505,000	June 30, 1924	2,317,157	SW¼ sec. 25	6,100	Oct. 12, 1920	1,123,934
NE¼ sec. 12	625,000	Mar. 18, 1926	1,143,696	SE¼ sec. 25	52,000	Oct. 12, 1920	1,178,425
NW¼ sec. 12	216,000	Mar. 18, 1925	1,019,162	NE¼ sec. 26	310,000	Apr. 5, 1923	1,080,017
SW¼ sec. 12	335,000	Dec. 18, 1924	1,995,706	NW¼ sec. 26	670,000	Mar. 19, 1924	1,144,392
SE¼ sec. 12	300,000	Mar. 18, 1925	1,219,581	SW¼ sec. 26	395,000	Mar. 19, 1924	368,153
NE¼ sec. 13	230,000	June 30, 1924	868,743	SE¼ sec. 26	805,000	June 28, 1922	739,193
NW¼ sec. 13	405,000	June 30, 1924	389,010	NE¼ sec. 35	495,000	June 28, 1922	640,060
SW¼ sec. 12	1,825,000	Mar. 18, 1924	1,274,518	NW¼ sec. 35	205,000	Mar. 19, 1924	151,587
SE¼ sec. 13	1,580,000	Mar. 18, 1924	840,197	SW¼ sec. 35	12,000	Mar. 18, 1926	42,561
NE¼ sec. 14	225,000	June 30, 1924	451,908	SE¼ sec. 35	665,000	June 28, 1922	1,364,170
NW¼ sec. 14	1,990,000	Mar. 19, 1924	478,529	NE¼ sec. 36	2,000	Nov. 9, 1918	1,854,615
SW¼ sec. 14	1,790,000	Mar. 18, 1924	691,318	NW¼ sec. 36	800	Nov. 9, 1918	310,655
SE¼ sec. 14	1,955,000	Mar. 18, 1924	1,084,890	SW¼ sec. 36	1,765,000	Nov. 9, 1918	1,765,618
NE¼ sec. 15	800,000	Apr. 5, 1923	2,201,634	SE¼ sec. 36	7,000	Nov. 9, 1918	663,418
T. 26 N., R. 6 E.							
NW¼ sec. 2	$52,000	Dec. 12, 1927	189,683	NW¼ sec. 11	$75,000	Mar. 28, 1927	2,022,085
SW¼ sec. 2	600,000	Dec. 12, 1927	717,090	SW¼ sec. 11	112,000	Mar. 29, 1928	197,271
NE¼ sec. 3	645,000	Mar. 28, 1927	1,404,458	NW¼ sec. 14	145,000	Sept. 27, 1928	43,082
NW¼ sec. 3	34,000	Dec. 12, 1921	29,275	SW¼ sec. 14	171,000	Sept. 27, 1928	75,917
SW¼ sec. 3	1,900	Mar. 28, 1927	3,696	NE¼ sec. 15	4,100	Mar. 28, 1927	25,627
SE¼ sec. 3	465,000	Dec. 12, 1927	773,064	NW¼ sec. 15	61,000	Dec. 12, 1921	294,214
NE¼ sec. 4	205,000	Dec. 12, 1921	567,424	SW¼ sec. 15	25,000	Mar. 18, 1925	69,453
NW¼ sec. 4	360,000	June 14, 1921	1,256,704	SE¼ sec. 15	188,000	Sept. 27, 1928	372,917
SW¼ sec. 4	251,000	Oct. 12, 1920	1,347,065	NE¼ sec. 16	136,000	June 14, 1921	622,569
SE¼ sec. 4	95,000	Oct. 12, 1920	829,839	NW¼ sec. 16	5,400	Feb. 3, 1920	1,345,786
NE¼ sec. 5	800	Nov. 9, 1918	1,311,313	SW¼ sec. 16	380,000	April 5, 1923	1,494,088
NW¼ sec. 5	900	Nov. 9, 1918	1,074,780	SE¼ sec. 16	127,000	April 5, 1923	770,966
SW¼ sec. 5	700	Nov. 9, 1918	1,143,065	NE¼ sec. 17	500,000	Dec. 12, 1921	744,540
SE¼ sec. 5	500	Nov. 9, 1918	1,410,620	NW¼ sec. 17	235,000	June 28, 1922	151,499
NE¼ sec. 6	310,000	June 14, 1921	796,779	SW¼ sec. 17	5,200	Mar. 18, 1925	1,078
NW¼ sec. 6	6,600	Nov. 9, 1918	740,223	SE¼ sec. 17	11,000	Jan. 18, 1923	664,577
SW¼ sec. 6	206,000	June 14, 1921	928,162	NE¼ sec. 20	42,000	Dec. 18, 1924	563,959
SE¼ sec. 6	100,000	June 14, 1921	606,321	NW¼ sec. 20	1,000	Sept. 30, 1926	11,804
NE¼ sec. 7	155,000	Dec. 12, 1921	362,217	SE¼ sec. 20	110,000	Mar. 18, 1926	333,489
NW¼ sec. 7	175,000	Dec. 12, 1921	398,549	NE¼ sec. 21	99,000	Dec. 18, 1924	866,047
SE¼ sec. 7	275,000	June 28, 1922	49,688	NW¼ sec. 21	176,000	Dec. 18, 1924	1,313,674
NE¼ sec. 8	300,000	June 14, 1921	890,106	SW¼ sec. 21	526,000	Mar. 18, 1926	962,164
NW¼ sec. 8	115,000	June 14, 1921	628,301	SE¼ sec. 21	321,000	Mar. 18, 1926	628,822
SW¼ sec. 8	300,000	Dec. 12, 1921	541,028	NE¼ sec. 22	18,200	Mar. 29, 1928	355,108
SE¼ sec. 8	351,000	June 14, 1921	1,110,761	NW¼ sec. 22	29,000	Mar. 18, 1926	42,044
NE¼ sec. 9	500	Nov. 9, 1918	959,740	SE¼ sec. 22	10,200	Mar. 29, 1928	13,197
NW¼ sec. 9	3,600	Nov. 9, 1918	533,915	NE¼ sec. 28	233,000	Sept. 30, 1926	356,646
SW¼ sec. 9	3,000	Nov. 9, 1918	1,171,852	NW¼ sec. 28	415,000	Sept. 30, 1926	660,449
SE¼ sec. 9	3,000	Nov. 9, 1918	1,636,370	SW¼ sec. 28	251,000	Mar. 28, 1927	520,338
NE¼ sec. 10	95,000	Dec. 12, 1927	35,528	SE¼ sec. 28	16,000	Mar. 28, 1927	29,508
NW¼ sec. 10	200,000	June 14, 1921	767,857	NE¼ sec. 29	50,000	Sept. 30, 1926	76,641
SW¼ sec. 10	200,000	June 14, 1921	673,595	NW¼ sec. 33	31,000	Sept. 20, 1929	98,007
SE¼ sec. 10	50,000	Sept. 27, 1928	55,236	SE¼ sec. 33	26,000	Sept. 27, 1928	73,654

Oil produced in the Burbank field—Continued

T. 27 N., R. 6 E.

Tract	Bonus paid for lease	Date of sale of lease	Production to end of 1938 (barrels)	Tract	Bonus paid for lease	Date of sale of lease	Production to end of 1938 (barrels)
NE¼ sec. 7	$42,000	Sept. 30, 1926	54,580	SE¼ sec. 28	$61,000	Mar. 2, 1923	1,172,662
NW¼ sec. 7	455,000	Sept. 30, 1926	837,441	NE¼ sec. 29	600,000	June 28, 1922	1,143,005
SW¼ sec. 7	420,000	Mar. 18, 1926	619,291	NW¼ sec. 29	1,000,000	June 28, 1922	1,506,129
SE¼ sec. 7	222,000	Mar. 18, 1926	1,081,402	SW¼ sec. 29	650,000	Dec. 12, 1921	1,118,1[illegible]8
SW¼ sec. 8	40,000	June 14, 1921	592,610	SE¼ sec. 29	410,000	Mar. 2, 1922	1,399,010
NW¼ sec. 17	82,000	Mar. 2, 1922	1,309,121	NE¼ sec. 30	700,000	Dec. 12, 1921	1,019,502
SW¼ sec. 17	38,000	Mar. 18, 1925	190,845	NW¼ sec. 30	663,000	Dec. 12, 1921	920,762
SE¼ sec. 17	61,000	Mar. 28, 1927	867,084	SW¼ sec. 30	26,000	Dec. 12, 1921	1,183,083
NE¼ sec. 18	54,000	June 30, 1924	833,051	SE¼ sec. 30	250,000	June 14, 1921	840,303
NW¼ sec. 18	141,000	June 30, 1924	602,733	NE¼ sec. 31	1,300	Nov. 9, 1918	1,773,341
SW¼ sec. 18	605,000	June 30, 1924	866,070	NW¼ sec. 31	3,100	Nov. 9, 1918	1,634,482
SE¼ sec. 18	285,000	Mar. 18, 1924	330,736	SW¼ sec. 31	7,100	Nov. 9, 1918	1,023,711
NE¼ sec. 19	615,000	Jan. 18, 1923	726,067	SE¼ sec. 31	3,000	Nov. 9, 1918	998,781
NW¼ sec. 19	1,100,000	Jan. 18, 1923	1,790,662	NE¼ sec. 32	600,000	Dec. 12, 1921	1,270,671
SW¼ sec. 19	1,185,000	June 28, 1922	2,128,525	NW¼ sec. 32	226,000	June 14, 1921	1,057,795
SE¼ sec. 19	1,050,000	June 28, 1922	1,877,449	SW¼ sec. 32	305,000	June 14, 1921	1,192,469
NE¼ sec. 20	8,000	Mar. 18, 1926	741,524	SE¼ sec. 32	800,000	Dec. 12, 1921	1,552,309
NW¼ sec. 20	75,000	Mar. 19, 1924	151,155	NE¼ sec. 33	160,000	Mar. 2, 1922	5,579
SW¼ sec. 20	415,000	Jan. 18, 1923	986,903	NW¼ sec. 33	300,000	Dec. 12, 1921	745,673
SE¼ sec. 20	24,000	Mar. 19, 1924	327,351	SW¼ sec. 33	600,000	Dec. 12, 1921	978,109
NW¼ sec. 21	300,000	Dec. 12, 1927	560,095	SE¼ sec. 33	115,000	Dec. 12, 1921	139,005
SW¼ sec. 21	655,000	Mar. 29, 1928	949,769	NE¼ sec. 34	300	Mar. 18, 1926	351,039
SE¼ sec. 21	200,000	Mar. 29, 1928	247,884	NW¼ sec. 34	300	Mar. 18, 1926	1,503,300
NW¼ sec. 27	20,000	Dec. 12, 1927	21,722	SW¼ sec. 34	75,000	Mar. 2, 1922	835,311
SW¼ sec. 27	555,000	Mar. 28, 1927	763,383	SE¼ sec. 34	300	Mar. 18, 1926	1,248,530
NE¼ sec. 28	405,000	Dec. 12, 1927	1,329,476				
NW¼ sec. 28	205,000	June 28, 1922	150,937		65,308,000		163,540,737
SW¼ sec. 28	280,000	Mar. 2, 1923	598,593				

SOUTH BURBANK FIELD

The South Burbank field in Tps. 25 and 26 N., R. 6 E., was discovered January 4, 1934, by well 1 of the Mead Oil Co., Al Beck, Bridgeport Machine Co., and others, in the NE¼SW¼ sec. 10, T. 25 N., R. 6 E., which produced initially 1,650 barrels a day from the Burbank sand. Most of the field was systematically developed during the three years following its discovery. The extension southward from the discovery well showed that the oil pool is continuous with the old Fairfax pool in secs. 21, 22, and 28, T. 25 N., R. 6 E., which was discovered January 26, 1926, by the Prairie Oil and Gas Co.'s well 1 in the southwest corner of the SE¼ sec. 21, T. 25 N., R. 6 E. The initial daily yield of the discovery well of the Fairfax pool was 560 barrels, natural flow, but three of the wells offsetting it proved to be dry holes. Most of the wells in the field had small daily yields, and development of the field therefore progressed slowly. Many wells have been drilled in the vicinity, however, since the discovery of the South Burbank pool, and the northeast limit of this field is still not defined. The oil pool of the old Fairfax field is practically separated from the main South Burbank pool by a sandy shale barrier, as is shown by the low reservoir pressures, small initial yields of the wells, and shaly character of the sand in the S½ sec. 15 and in parts of sec. 16.

As developed to date the South Burbank field, including the Fairfax pool, is about 7 miles in length and 1½ miles in greatest width. About 280 wells have produced oil, and all except a few of these are still producing. The initial daily yields of the wells ranged from 10 to 5,786 barrels.[16] Most of the wells flowed at first, and all except a few still flow, owing to the maintenance of the reservoir pressure, at a slowly declining rate, by the return of gas to the reservoir sand.

Soon after the South Burbank field was discovered, 16 operators, controlling an area of 2,720 acres,[17] 2,277 acres of which are in the producing area of the field, pooled their interests and assigned the operation of their respective properties to one company, each operator retaining his proportionate interest in the unit. The individual interest of each was determined from the initial yields of the wells on each tract, for it was found in the old Burbank field that the initial yields bore a definite relation to the ultimate recoveries.[18] Under the unit operation, which began functioning in June 1935, the gas produced from the pool is separated of its gasoline and then returned to the reservoir under pressure. Thus the pressure in the reservoir is maintained at a slowly declining rate, the flowing life of the wells is prolonged, and the amount of oil ultimately recovered is expected to be much greater than it could have been under individual management. Estimates place the ultimate recovery to be expected in the unit at from 15,000 to 16,000 barrels to the acre. Economies such as the wider spacing of wells and the avoidance of duplication in field equipment, labor, and overhead expense are made possible by this unit operation.[19]

Early in the existence of the unit all the gas produced was returned to the reservoir, and, in addition, some was purchased outside the unit and injected. The amount injected has since been reduced somewhat—during 1939 only about 70 percent of the gas produced in the unit block of properties was returned to the reservoir sand. Soon after the unit operation got under way operators of properties totaling about 1,880 acres outside the unit block began returning gas to the sand, and by 1938 essentially the entire field except the old Fairfax pool was being operated under a pressure-maintenance program. As a result, at the beginning of 1940 all the wells in the South Burbank field except 10 within the unit block and 21 outside the block, exclusive of those in the old Fairfax pool, were still flowing. The per-acre yield from the pool of 5,500 barrels up to January 1, 1940, therefore, was nearly all produced by flowing.

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[16] Markham, E. O., and Lamar, L. C., South Burbank pool, Osage County, Okla.: Am. Assoc. Petroleum Geologists Bull. vol. 21, no. 5, pp. 561, 564, 1937.

[17] Salnikov, I. S., and Haider, M. L., Pressure maintenance and unitization—South Burbank pool: Oil Weekly, vol. 85, no. 13, p. 34, June 7, 1937.

[18] Idem.

[19] Idem., p. 36.

It is noteworthy that only about 4,000 barrels to the acre was produced by flowing in the old Burbank field,[20] where pressure maintenance was not practiced. The reservoir pressure which in parts of the South Burbank field was originally between 1,000 and 1,100 pounds and which averaged 910 pounds for the entire field, dropped to an average of 386 pounds on January 1, 1940.

During 1936 the gas-oil ratio in the unit block of properties increased from 1,160 cubic feet to the barrel in January to 1,900 cubic feet to the barrel in December.[21] The gas-oil ratio continued to rise steadily until early in 1939, when it had reached about 4,200 cubic feet to the barrel. Approximately this ratio was maintained during 1939, mainly by (1) reducing the rate of oil production, (2) reducing the volume of gas injected into the reservoir, (3) shutting in the wells having high gas-oil ratios and producing only from those whose gas-oil ratios were low, and (4) using specially constructed packers by which the main part of the gas-bearing sand is sealed off from the well.[22]

A total of 24,520,500 barrels of oil had been produced from the South Burbank field exclusive of the Fairfax pool by January 1, 1940.

POSSIBILITY OF UNDISCOVERED OIL AND GAS POOLS

ORIGIN OF THE SAND BODIES

That other sand bodies besides those of the Burbank and South Burbank fields were formed in the western part of Osage County simultaneously with those bodies is suggested not only by the present but by earlier investigations.[23] The conclusions reached as a result of these investigations are that the sand bodies of the Burbank and South Burbank pools were deposited as offshore bars on the western shore of an ancient sea during the Cherokee stage of the Pennsylvanian epoch and that the shore line of that sea extended into Kansas, northward across Cowley County and thence northeastward into northern Greenwood County, a distance altogether of about 75 miles from the Burbank field. Much of the course of this ancient shore line in Kansas is marked by oil-bearing sands, which are known as shoestring sands.

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[20] Salnikov, I. S., oral communication.

[21] Salnikov, I. S., and Haider, M. L., Pressure maintenance and unitization—South Burbank pool: Oil Weekly, vol. 85, no. 13, p. 37, June 7, 1937.

[22] Idem., pp. 38–39.

[23] Bass, N. W., Leatherock, Constance, Dillard, W. R., and Kennedy, L. E., Origin and distribution of Bartlesville and Burbank shoestring oil sands in parts of Oklahoma and Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 21, no. 1, pp. 30–66, 1937. Bass, N. W., Origin of the shoestring sands of Greenwood and Butler Counties, Kans.: Kansas Geol. Survey Bull. 23, 1936.

The persistence of an almost uninterrupted chain of offshore bars along our Atlantic and Gulf shores suggests that the ancient Cherokee sea, whose offshore bars are known from well data to extend from northern Greenwood County, Kans., to the southern tip of the South Burbank pool, in Oklahoma, a distance of about 100 miles, may have been bordered by offshore bars still farther south, beyond the South Burbank field. If undiscovered sand bodies representing such offshore bars are present near the Burbank and South Burbank fields it is believed that they contain oil and gas, because the environment along the southern part of the old shore surely was like that of the area occupied by the Burbank and South Burbank fields.[24]

The only method in use so far of locating oil- and gas-bearing sand bodies of the offshore type is by drilling test wells—an expensive method, for the sand bodies in this part of Osage County lie at depths ranging from 2,850 to 3,000 feet. The results of the present investigation lead to the conclusion that the location of the areas likely to contain oil may be inferred mainly from a study of the initial daily yields of the oil wells in the Burbank and South Burbank fields. If the initial daily yields of all the oil wells of the Burbank and South Burbank fields are plotted on a map (see pl. 12), it is found that the wells with large initial daily yields lie in long, narrow belts. These belts parallel the curved eastern margins of both the reservoir sand bodies and the oil pools, and in the northern part of the Burbank field they curve westward so that they nearly parallel the northern margin of that field. Doubtless if all the wells could have been completed at the same time, the wells of large initial daily yield would have presented an even truer delineation of the belts. It was noted, however, during the development of the Burbank field that, owing to the relatively low permeability of the sand, the original gas pressures in the different parts of the field dropped very slowly as new wells nearby began to produce. Furthermore, the field was developed rapidly, and the producing area was expanded outward from the discovery well fairly regularly, with the wells spaced at one to each 10 acres.

An earlier investigation[25] of the thickness of the reservoir sand bodies of the two fields showed (1) that these sand bodies are large lenses ranging in thickness from a feather edge to more than 100 feet and (2) that they contain narrow curved belts of thick sand. These belts of thick sand lie parallel with the curved eastern margins of the sand bodies of the Burbank and South Burbank fields, but

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[24] Bass, N. W., Important new oil pools in Osage Indian Reservation, Okla., may be discovered: U. S. Dept. Interior Press Memo. 105714, Aug. 29, 1940.

[25] Bass, N. W., Leatherock, Constance, Dillard, W. R., and Kennedy, L. E., Origin and distribution of Bartlesville and Burbank shoestring oil sands in parts of Oklahoma and Kansas: Am. Assoc. Petroleum Geologists Bull., vol. 21, no. 1, pp. 30-66, 1937.

they curve westward in the northern part of the Burbank field and nearly parallel its northern margin.

The ridges of thick sand in the Burbank and South Burbank fields appear to represent beach-growth ridges that were formed exactly as such features are being formed on our coasts today, namely, by the addition of each newly-formed ridge on the seaward side of the beach. Growth ridges are particularly prominent at Cape Henry, Va., on Chesapeake Bay. At Cape Henry the growth ridges trend northward, and are parallel with the Atlantic shore along the southern part of the cape; but farther north they swing westward and are parallel with the Chesapeake Bay shore along the northern part of the cape. The curved trends of the ridges at Cape Henry are thus remarkably similar to the trends of the belts of thick sand and the belts containing wells with large initial yields in the Burbank field. From this analogy it would seem that the sand body of the Burbank field, like the large sand body that forms Cape Henry, grew progressively eastward and northward as a series of overlapping beaches, beginning at the southwest margin of the field.

Narrow sand bars parallel with the shore line are built by waves and longshore currents. The margins of a bar feather out into the fine-grained sediment of the adjacent deposits, but a longitudinal zone in the middle of a bar consists largely of well-sorted, clean sand and would accordingly be the most highly permeable part of the sand bar. Oil wells with large initial yields in the Burbank and South Burbank fields obtain their oil from the more permeable parts of the reservoir sands, and the narrow zones containing these wells are believed to be strips forming the middle portions of many overlapping sand bars that collectively form the large sand bodies of these fields.

During the long time required for the deposition of the large sand body of the Burbank field doubtless the crests of many ridges were planed off by waves, wind, and rain; and the swales between the ridges were filled. The surface relief of many of the bars that constitute the sand body was therefore destroyed, but the permeability and other characteristics of the sand persisted in the undestroyed parts of the bars.

The sand body of the Stanley stringer, as shown by its thickness and distribution, is a narrow bar-shaped body, extending southeastward without a break for many miles; but the alinement of the belts in accordance with the initial daily yields of the wells indicates that this sand body really consists of a series of relatively short, closely associated sand bars that trend northwest across the main sand body and have an offset arrangement, like the offset arrangement of sand bars on most of our modern coasts.

The offset arrangement of the belts in the Stanley stringer indicates the probable direction of the flow of the longshore currents that, together with waves, built the sand body of the Stanley stringer. Longshore currents operate on the seaward side of a bar. They move sand lengthwise along the bar and deposit it at its end, thus constantly extending the bar in the direction in which the currents flow. In many places the growing end of a bar is extended beyond the opposite end of the neighboring bar, and an offset in the shore line and in the crest lines of the bars is thus produced. The offset at the southeast end of the bar extending from sec. 7 to sec. 21, T. 27 N., R. 6 E., is the reverse of the offset at its northwest end. The next bar southeast of the southeast end of the bar in sec. 21 is offset to the southwest, and each succeeding bar southeastward along the Stanley stringer is also offset to the southwest. From the arrangement of these offsets, it is inferred that the longshore currents along the northeastern part of the sand body of the Burbank field flowed northwestward from the central part of the bar extending from sec. 21 to sec. 7, and that the longshore currents along the Stanley stringer flowed southeastward from the central part of this bar.

The offset arrangement of the individual segments of the Stanley stringer sand body apparently has not been generally recognized, for the wells in secs. 11 and 14, T. 26 N., R. 6 E., except those in the NW¼ NW¼ sec. 11, were drilled west of the southeastward-trending belt lying in the W½ sec. 11 and possibly extending into sec. 14.

SHIDLER AND STANLEY STRINGER-SOUTH BURBANK STAGES OF DEPOSITION

The shore of the Cherokee sea during the final stage of beach-sand deposition in the Burbank and South Burbank fields has been defined by drilling. It followed along the northern and eastern margins of the Burbank field, including the Stanley stringer, and the eastern margin of the South Burbank field. For convenience, this late stage is referred to herein as the Stanley stringer-South Burbank stage.

Many earlier positions of the shore line and accompanying beaches can be traced through the Burbank and South Burbank fields, particularly the Burbank, by means of the map that shows the belts containing wells with large initial daily yields. (See pl. 12.) One such shore line in the Burbank field extended eastward through the middle of the east half of T. 27 N., R. 5 E., into the western part of T. 27 N., R. 6 E., and thence curved southeastward, passing just west of Shidler. For convenience, the stage of beach-sand deposition indicated by this shore line is referred to as the Shidler stage.

The Burbank sand body formed during the Shidler stage is a large thick lens composed of many overlapping bars. A belt about a mile wide, which extends across the north end of this sand body and which was deposited during the last part of the Shidler stage, contains the most prolific oil-bearing sand in the Burbank field. Within this belt there are 17 tracts of 160 acres each that by the end of 1938 had yielded a total of 35,184,084 barrels, a little more than a sixth of the total amount produced from the entire Burbank field. Wells within these tracts have had both large initial and large total yields.

HYPOTHETICAL POOL OF THE SHIDLER STAGE

Probably other sand bodies, as yet unknown, were formed during the Shidler stage and occupied a narrow belt that extended for many miles along the ancient coast in a southwesterly direction from the sand body of the Burbank field. This probability is suggested by a comparison of the coast that existed during the Shidler stage with parts of the present coasts of the United States that are bordered with sand beaches for three quarters of their length. Sand bodies such as that at Cape Henry are associated with an almost continuous belt of sand bars that extends hundreds of miles southward along the coast.

The ancient shore extending southwestward from the Burbank sand body of the Shidler stage may have followed a line somewhat similar in its course to the course followed by the shore line at the close of the Stanley stringer-South Burbank stage. The suggestion that the shore lines existing at these two stages, which were separated by a very long period, had somewhat similar courses is justified by the fact that, in many places on our present coasts where several positions of the shore line are marked by growth ridges, the courses of the old shore lines appear to be roughly parallel with the present shore line. Also, in the Burbank field the belts containing thick sand and other belts containing wells with large initial yields are roughly parallel, indicating that the shore lines of the Shidler and Stanley stringer-South Burbank stages followed generally similar courses.

On the basis of this theory, the shore line of the Shidler stage and its associated sand bodies have been projected southwestward through T. 25 N., Rs. 5 and 6 E. (See fig. 2.) The hypothetical sand body that has been sketched in T. 25 N., Rs. 5 and 6 E., almost surely will be found to deviate a mile or more east or west from the position shown. The position suggested in the sketch merely represents one of many interpretations that can be made from the facts revealed by the wells in the developed oil fields. That such a sand body contains oil is indicated by the fact that its geologic history has been like that of the nearby sand bodies of the Burbank and South Burbank fields.

HYPOTHETICAL POOLS OF THE STANLEY STRINGER-SOUTH BURBANK STAGE

Large sand bodies almost certainly were deposited during the Stanley stringer-South Burbank stage along the shore southward

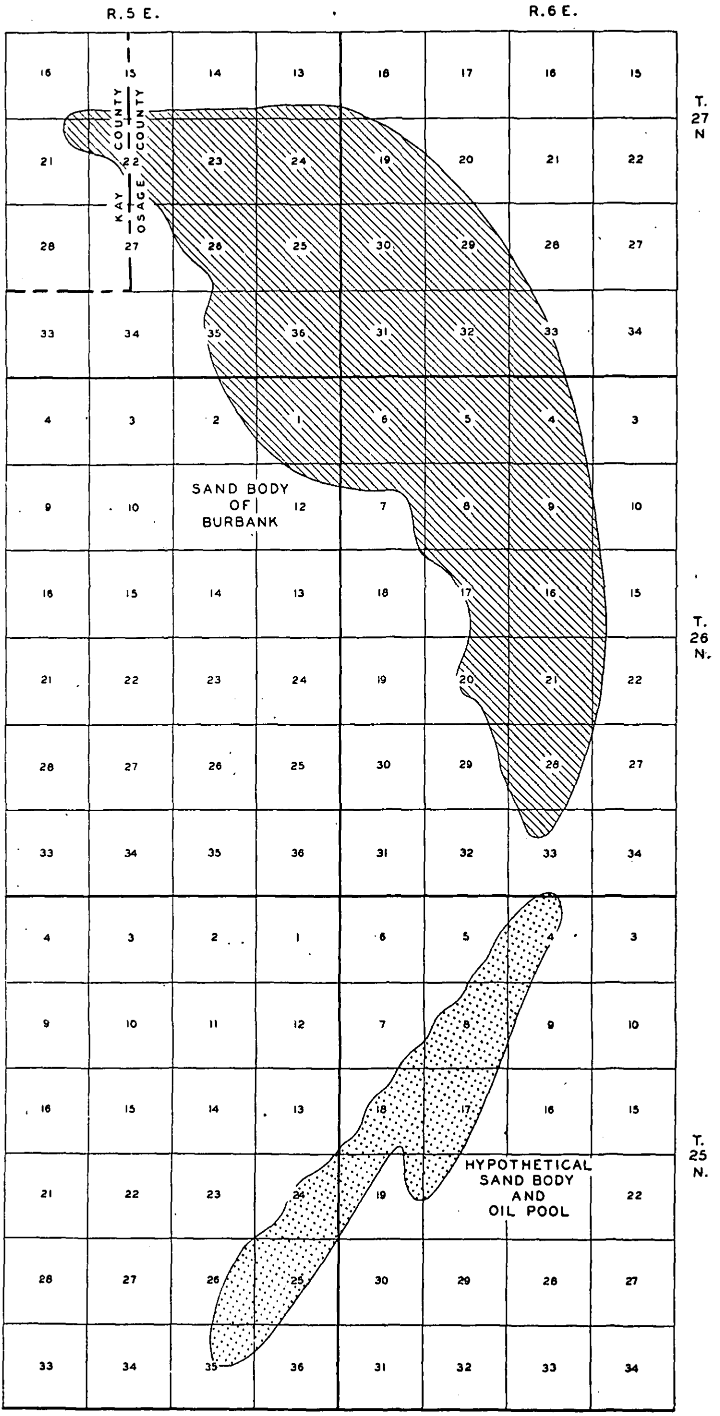

FIGURE 2.—Sketch at the close of the Shidler stage showing the sand body of the Burbank field and a hypothetical sand body.

from the South Burbank field. Assuming that they were not subsequently destroyed, a proper interpretation of the facts revealed by the wells in the Stanley stringer and the South Burbank field should lead to the discovery of these sand bodies. The alinement of the individual sand bars of the Stanley stringer belt has a progressive offset to the west (see pl. 12), but it is not certain whether this arrangement continues through the South Burbank field. The few facts available are capable of two interpretations. They suggest that during the early stages of sand deposition the currents flowed northeastward through the E½ sec. 16, NW¼NW¼ sec. 15, the middle of secs. 10 and 3, T. 25 N., R. 6 E., and the SE¼ sec. 34, NW¼ sec. 35, and SW¼ sec. 26, T. 26 N., R. 6 E. This northeasterly direction of the current, in contrast to the southeasterly direction of the current along the Stanley stringer part of the ancient shore, seems not unusual, because in some parts of our present coasts the direction of the offsets of the bars is reversed every few miles, indicating that the direction of the currents is reversed also. Some data suggest that the currents continued to flow northeastward at the end of the period of sand deposition along the eastern margin of the South Burbank field, and other data suggest that they flowed southwestward. Accordingly, two hypothetical sand bodies and two oil pools in the southern part of T. 25 N., R. 6 E., have been sketched on figure 3, one southwest and the other southeast of the South Burbank field.

APPLICATION OF THE INTERPRETATIONS

OTHER SAND-LENS POOLS

It appears probable that the interpretation afforded by the initial yields of wells described herein can be applied advantageously during the development by drilling of sand-lens pools other than the Burbank and South Burbank. The use of this method in guiding development while the drilling of wells is in progress should enable the operators to project the sites for new wells in systematically arranged belts. The finding of wells with small yields or dry holes on the margin of a belt would not necessarily indicate that the limit of the pool had been reached. Such wells may be revealing only the narrow belts of thin sand with low permeability that lie between belts of thick sand of high permeability, or they may indicate merely the position of narrow barren gaps that occur between the offset ends of two bars.

REPRESSURING

The determination of the relative permeability of the reservoir sand body throughout an oil field is important in planning for

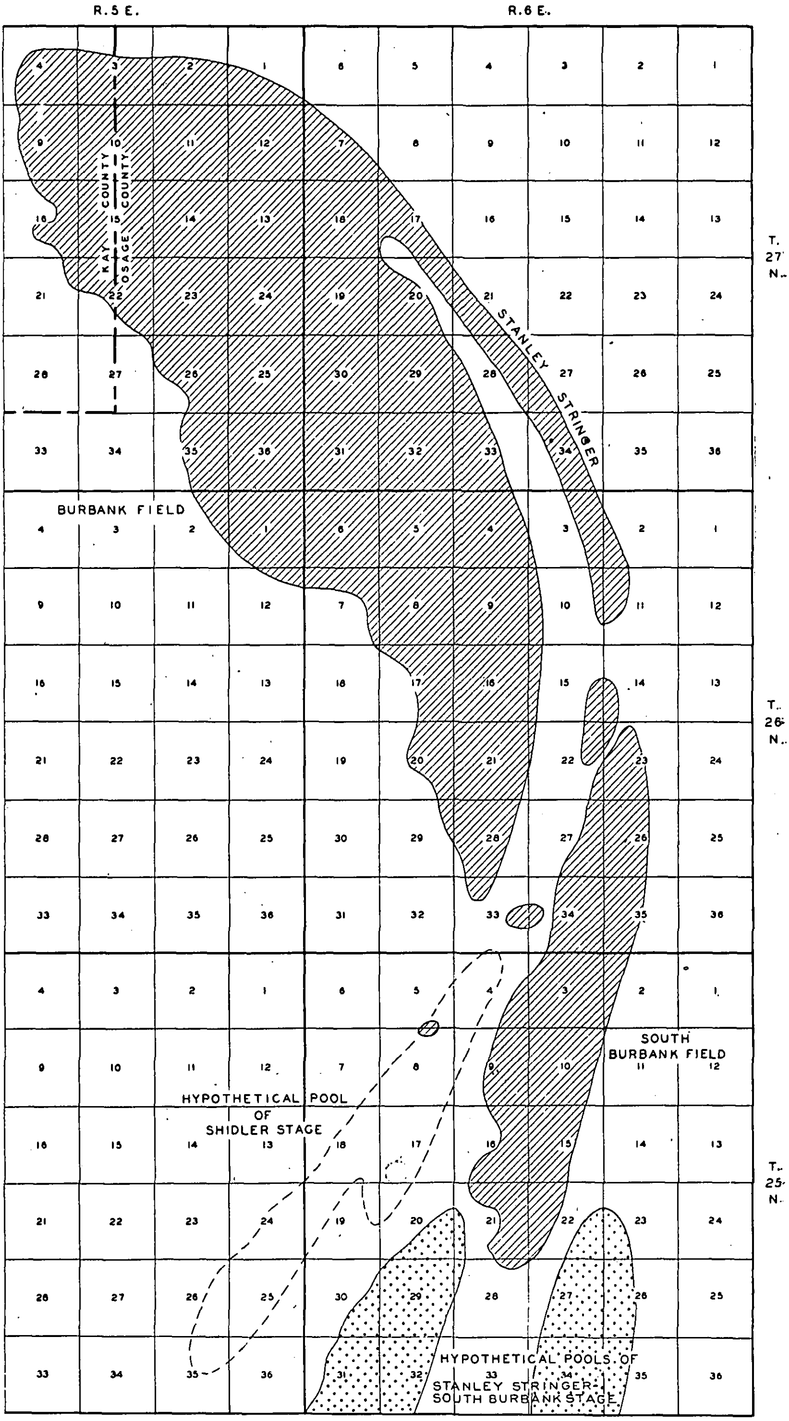

FIGURE 3.—Sketch at the close of the Stanley stringer-South Burbank stage showing the sand bodies of the Burbank and South Burbank fields and parts of hypothetical sand bodies.

repressuring the sand with gas or water. Such data are most likely to be acquired by laboratory-permeability tests made of cores of the sand taken specifically for that purpose. Where such cores are unavailable, however, it is believed that a map such as plate 12 will supply much information about the permeability of the sand that can be used in planning the repressuring project. The narrow belts containing wells whose initial daily yields have been large are believed to represent belts in which the sand has high permeability, and the belts containing wells whose initial daily yields were small are believed to represent belts in which the sand has relatively low permeability. The intake (or pressure) wells should be distributed along the belts in such a manner as to allow for the changes in permeability laterally from one belt to another rather than at equidistant sites throughout the pool. Inasmuch as the belts cross leased properties of different ownerships, any plan for locating intake wells along the belts would necessitate the cooperation of many owners. Some sort of a unit plan of operation for relatively large parts of the field, therefore, would be necessary to make such a plan practicable.

A similar scheme apparently was used in planning the pressure-maintenance project carried out on the South Burbank field in 1934 and 1935.[26]

Recent results in water-flooding a shoestring-sand body in the Cherokee shale near Chanute, Kans., have shown that the flood water in a sand body travels faster lengthwise than crosswise.[27] Inasmuch as the sand body at Chanute lies near the stratigraphic position of the the Burbank sand and is believed to have been formed in much the same way as the Burbank sand, the behavior of the water injected into the sand is noteworthy; it appears to bear out the contention that the most permeable parts of sands of this type lie in belts that trend lengthwise.

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[26] Salnikov, I. S., and Haider, M. L., Pressure maintenance and unitization, South Burbank pool: Oil Weekly, vol. 85, no. 13, p. 34, June 7, 1937.

[27] Dillard, W. R., Oak, D. P., and Bass, N. W., Chanute oil pool, Neosho County, Kansas, a water-flooding operation: Am. Asso. Petroleum Geologists, Stratigraphic Type Oil Fields, pp. 72–73, 1941.