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OIL AND GAS IN OKLAHOMA

PETROLEUM GEOLOGY IN OKLAHOMA

By

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FOREWORD

In 1917 the Oklahoma Geological Survey issued Bulletin 19, Part II, "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 the 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 the 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 year 1926, and doubtless new data will cause many changes in our present ideas.

The author of this chapter, Dr. Sidney Powers, has a wide acqaintance with the working geologists of Oklahoma, and especially with the men engaged in petroleum research. For this reason, he is particularly well fitted to write the chapter on the history of oil geology in the State.

CHAS. N. GOULD,
Director.

Dec. 15, 1926.

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INTRODUCTION

This paper traces the history and development of petroleum geology in the State of Oklahoma. The first portion discusses the geologists who came in order of their arrival and the second part traces the discovery and development of oil fields in the petroleum industry treated chronologically.

HISTORY

The first geologist to engage in commercial petroleum work in what is now Oklahoma was H. B. Goodrich who went from Houston to Ardmore in 1903 for the Santa Fe Railway Co. Mr. Goodrich commenced his petroleum work in a consulting capacity in New Brunswick in 1899 where he located the Stony Creek gas field and an oil well at Pre d' en Haut, St. Joseph's College. He has been engaged exclusively in commercial work ever since. He was attracted to Indian Territory by reported seepages and later read Eldridges's report[1] on oil seepages.

He located the first Santa Fe (now Coline Oil Co.) well at the prolific Wheeler oil seepages in May, 1904. This well encountered mechanical difficulties and did not strike gas until the fall of 1904. In other wells drilled during the next year oil was found at shallow depths before the discovery of Glenn Pool and the oil field still produces. A commercial supply of gas was developed and a pipe line to Ardmore was completed in 1907 before the piping of gas to Oklahoma City.

Mr. Goodrich remained with the Santa Fe until 1910 doing some consulting work for other clients. From 1910 to 1911 he was in Bolivia exploring for oil. He made a report on the Cushing field for the U. S. Bureau of Mines in 1913-14, which was not published, and was engaged with the Dundee Petroleum Co., during the development of the Healdton field in 1915, moving to Tulsa and reentering consulting practice in 1915.

Scientific geological work in Indian Territory by the U. S. Geological Survey under the direction of J. A. Taff and others play-

1. Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey, 22nd An. Report, pt. 1, pp. 209-452, 1901.

ed an important part in directing the attention of early commercial work to the southeastern portion of Oklahoma where a number of anticlines similar to the Appalachian folds of the Pennsylvanian and West Virginian oil fields were mapped. Oil sands crop out in the Ouachita Mountains near Redden in Atoka County and Jumbo in Pushmataha County; and gas seepages occur in the folded Pennsylvanian strata at Soda Springs in sec. 35, T. 12 N., R. 17 E., east of Checotah, and on Ash Creek 15 miles northeast of McAlester, yet only gas has been produced in this highly folded region.

The second important scientific contribution to Oklahoma geology was by the Oklahoma Geological Survey founded by Chas. N. Gould in 1908. Reports prepared by instructors and students of Oklahoma University and published by this Survey had a direct bearing on the development of Cushing, Newkirk, Ponca City, and other oil fields. Reports by the Federal Survey, also aided in the development of Glenn Pool, Healdton, Billings, Bristow, the Osage, and other fields. General descriptions of Oklahoma oil fields were published by the Oklahoma Geological Survey (Bull. 2, by L. L. Hutchison in 1911; Bull. 19, pt. 2, by C. W. Shannon et al, 1917), by the Federal Survey (Bull. 531 b, by R. H. Wood, 1913), and by L. C. Snider (Petroleum and Natural Gas in Oklahoma, Oklahoma City, 1913; Oil and Gas in the Mid-Continent Field, Oklahoma City, 1920).

Among the scientific workers in Oklahoma who later engaged in commercial work are M. J. Munn, Carl D. Smith, Robert H. Wood, and Everett Carpenter of the Federal Survey, and Chas. N. Gould, Pierce Larkin, L. L. Hutchison, D. W. Ohern, Frank Buttram, Irving Perrine, Chas. H. Taylor, L. C. Snider, and many others of the State Survey.

Mr. Gould commenced teaching at Oklahoma University in 1900 and engaged in consulting work during summer vacations, beginning in 1906 in the area between Muskogee and McAlester, part of which had been mapped previously by J. A. Taff for the Federal Survey. I. C. White checked this work for the Deming Investment Company the same summer. Mr. Gould resigned from the State Survey in October, 1911, and was employed by the Mid-Continent Co., detailing the Poteau gas field structure. During the summer of 1913 he was engaged in a consulting capacity by the Wichita Natural Gas Co., (now the Empire Gas and Fuel Co.) for one year, and on August 1st, he employed Everett Carpenter as Chief Geologist and several other geologists including J. Russell Crabtree. Mr. Gould and Mr. Carpenter visited a shallow gas well at Augusta, Kansas, in 1913, and outlined the Augusta anticline. They also saw the El Dorado anticline. Mr. Crabtree mapped in detail the latter anticline which had been discovered previously by Professor Erasmus Haworth of Kansas University. The dry hole drilled after the discovery was later offset by production.

L. L. Hutchison began his career as a petroleum geologist in the fall of 1906 when a senior at Oklahoma University and reported on the first oil well near Madill for the Deming Investment Company. He was engaged by them from time to time until the fall of 1907. In the summer of 1908 he assisted Dr. Gould in organizing the State Survey and was Assistant Director until the fall of 1910 when he moved to Tulsa. He opened an office as Consulting Geologist in the Robinson building, in the spring of 1911, and was the first geologist to locate in Tulsa. His first work there was for Grant Stebbins. He reported on the Cushing area for T. B. Slick when the discovery well was being started and his best known work was for the McMan Oil Co., in the Cushing field in February, 1913, locating the Dropright dome. In 1912 he located the Haskell gas field. From July 1913 until 1915 he was an officer of the Kanola Oil Co., later the Kanola Oil & Refining Co.

Roswell H. Johnson was the second geologist to devote his time exclusively to petroleum exploration in Oklahoma. He maintained an office as consulting geologist in Bartlesville from the summer of 1908 until 1912. He was the first geologist to advertise in Oklahoma although Goodrich, Clapp, and others had advertised elsewhere. Among Mr. Johnson's clients were the Sagamore Oil Co. (owned by his father) and its successor, the Central Fuel Oil Co. He located the Red Oak, Latimer County, and Legal, Coal County, gas wells north of the Choctaw fault and in the area previously mapped by Taff.

Pierce Larkin, originally of the class of 1906, was one of the first students of Oklahoma University to enter petroleum geology. He started commercial work at Durant in October, 1908, and located the Ada gas field, now producing oil as well as gas, in June, 1909. He was engaged exclusively in consulting petroleum work from 1909 to 1912, with headquarters in Norman and since 1913, in Tulsa. Among his clients have been the McMan Oil Co. and the Prairie Oil and Gas Co. The extensive holdings of the McMan Oil Co. at El Dorado, Kansas, were secured on his recommendations. The Robberson field was located on his geology.

Hans Hirschi, then Chief Geologist for the Royal Dutch interests, came to Bartlesville in 1910 to report on the properties of the Barnsdall Oil Co., which were offered for sale. His report was not acted upon and the Royal Dutch did not enter the Mid-Continent field until 1912. Dr. Hirschi resigned in 1910 and returned to Bartlesville in the fall of 1911 as Chief Geologist for the Union des Pétroles d'Oklahoma (Oklahoma State Oil Co., Oklahoma Producing and Refining Corp.). He was in Oklahoma at various times from 1911 to 1913. Under his direction the first oil well south of Tiger Flats was drilled in sec. 1, T. 10 N., R. 11 E., finding a considerable volume of gas, but only about 10 barrels of oil.

Ed. Bloesch and Emil Kluth came to Bartlesville with Dr. Hirschi in 1911, and therefore the latter is entitled to the credit of estab-

lishing the first geological department for an oil company. Their principle work was between the Kansas line on the north and Stigler and Wewoka on the south and several oil fields were developed on the anticlines which they mapped. Dr. Bloesch became Chief Geologist in 1913 and resigned in 1915 to enter consulting work in Okmulgee and later in Tulsa. Mr. Kluth later became Chief Geologist of the Minnehoma Oil Co. in Tulsa and since 1922 has held a similar position with the Geo. F. Getty interests in Los Angeles. Dr. Otto Fischer came to Tulsa in 1913 for the Oklahoma State Oil Co. and was their Chief Geologist from 1915 until 1918. For the next five years he was associated with Dr. Bloesch in consulting work and then moved to West Virginia.

W. S. Vandruff and his son, Ross E. Vandruff, originally from Waynesburg, Penn., were associated in petroleum geology from 1903 until the death of the former in 1922. In 1910 they located the Limestone Run Oil Pool in Jefferson Co., Ohio, for Mr. Carnill, the founder of the Hill Oil and Gas Co., and in 1911, they came to Oklahoma for that company. After inspecting the country from trains they made more detailed sections from Kellyville through Olive to Cushing and in March, 1911, mapped the Shamrock dome of the Cushing field, prior to the location of the Shaffer and Smathers discovery well, using a five foot contour interval. The Hill Oil and Gas Co. sold their extensive holdings at Shamrock to Cosden and Co., in 1916. The Vandruffs later worked in the Yale area for B. B. Jones, discovered a dome northwest of Hominy (sec. 8, T. 23 N., R. 8 E.), and mapped the Blackwell anticline. Their subsequent work was done in California.

Early in 1912, Dr. J. Erb, then Chief Geologist for the Dutch Shell, inspected the Mid-Continent field and in July, 1912, A. W. Lauer was employed by Peter Kruisheer, the mechanical engineer in charge of their exploration. Mr. Lauer reported on properties in the shallow fields offered for sale. He returned to college in the fall and in 1913 went to Mexico for them. Their next geologist was R. A. Conkling, employed by them at the Hague in 1914, while Dr. Erb, G. D. Van Wyjk and E. Blumer made trips to Oklahoma. Mr. Conkling was Chief Geologist for the Roxana Petroleum Corp. for a number of years and is now engaged in consulting work.

J. H. Jenkins, who had been employed by W. T. Griswold, F. M. Hutchinson, and E. W. McCrary, Consulting Geologists in Marietta, Ohio, came to Tulsa in October, 1912, for W. T. Griswold, but soon began consulting work and checked the Billings dome for the Midco Petroleum Co. He was their Chief Geologist for many years and is now vice-president of the Tidal Oil Co., at Fort Worth, Texas.

F. G. Clapp, who had opened an office as Consulting Geologist in Pittsburgh, Pa., in 1908, came to Oklahoma in the fall of 1912 and spent the winter making a reconnaissance survey of the eastern Osage and of portions of Rogers, Washington, and Tulsa counties. This work was done for subsidiaries of the Bartlesville Zinc Co. In 1916 and 1917 he made an extensive survey of Grady, Garvin, and adjacent counties. He mapped the structure and predicted production of the Kilgore, Cement, and Two-Four (Stephens Co.) fields.

The year 1913 marked the permanent establishment and recognition of petroleum geology in the Mid-Continent field although many operators still retained their hostile attitude. E. W. McCrary, who arrived Jan. 1st, organized for Guffey & Gillespie the first geological department in Tulsa and introduced the method of planetable mapping which was developed by W. T. Griswold and others of the U. S. Geological Survey in the Appalachian field. Mr. McCrary had been engaged in consulting work in Marietta, Ohio, since 1908, and did the first commercial planetable mapping in West Virginia that year. In 1910 he mapped the Salt Creek, Wyoming, anticline. He mapped the Billings anticline and several other fields and mapped the domes which comprise the Cushing anticline. Besides being Chief Geologist for Guffey & Gillespie he also did consulting work until 1920, and was Chief Geologist for the Tidal Oil Co. from then until 1925, when he resigned to become an independent operator.

M. M. Valerius opened an office as Consulting Geologist at Sapulpa in January, 1913, and worked in the Cushing field. After spending a few months at the Missouri School of Mines, he joined V. H. McNutt in partnership in July, 1913, with offices in the Clinton Building, Tulsa. V. H. Hughes joined the partnership a year later. This partnership lasted several years and work was conducted in the Rocky Mountain states as well as in the Mid-Continent. Mr. McNutt came to Tulsa in May 1913. These three geologists are still engaged separately in consulting work and as independent operators.

F. Julius Fohs resigned from the Kentucky Geological Survey in 1912, and James H. Gardner resigned from the Pennsylvania Geological Survey the same year to engage in commercial petroleum geology at Lexington, Kentucky, but their engagements took them elsewhere and Mr. Fohs made a trip to Tulsa in the spring of 1913. He was so favorably impressed with the opportunities that he returned to Tulsa and the Lexington office was closed. Mr. Gardner joined him in Tulsa in the fall of 1913. This successful partnership of Fohs and Gardner lasted several years. One of the important developments which they instigated was the discovery of the Boynton oil field in 1914 for A. E. Humphreys. They also prepared the first correlation chart of Oklahoma oil sands, published by the Fuel Oil Journal, August, 1914. In 1917 the discovery well at Billings was drilled on the recommendation of Mr. Fohs.

Mowry Bates came to Tulsa late in 1913, and worked as a tool-dresser. He was employed by the Gypsy Oil Co. a year later and

was transferred to Shreveport early in 1915. He returned to Tulsa in partnership with Dorsey Hager in 1916. This partnership was dissolved in 1917. From then until his death in November, 1926, Mr. Bates was engaged in consulting work first in Tulsa and later in California.

D. W. Ohern and Frank Buttram resigned from the Oklahoma Geological Survey in the fall of 1913, and joined the Fortuna Oil Co., early in 1914. The conspicuous success of this company was based on geology and it opened the Yale, Cement, Morrison, Ripley and Ingalls oil fields and Cushing gas field. During the summer of 1912 Dr. Ohern had done consulting work, but most of his summers prior to 1914 were spent in mapping areal and structural geology for the Federal and State Surveys. His maps were a stimulus to the development of several oil fields. Mr. Buttram made a planetable survey of Cushing for the State in 1913. After the sale of the Fortuna Oil Co. to the Magnolia Petroleum Co., in 1920, Mr. Buttram organized the Buttram Petroleum Co., and Dr. Ohern the Borealis Oil Co.

Irving Perrine, then a professor at Oklahoma University, was employed part of the summer of 1913, by E. W. Marland and others and continued to do consulting work intermittently until he became Chief Geologist of the Pierce Oil Corp., in 1915. The geological department of the Marland interests, whose work has been influential in furthering the interests of petroleum geology, was subsequently headed by L. E. Trout, F. P. Geyer, Fritz L. Aurin, and Glenn C. Clark in succession. Mr. Perrine has been engaged in consulting work since 1917 and is now associated with W. C. Kite in Oklaoma City. Mr. Perrine discovered the Walters gas field.

Consulting geologists were in great demand in 1913, for at this time operators began to appreciate the value of structure mapping. In 1914 the word "structure" was used for the first time by oil operators. This was due partly to mapping of the Cushing anticline.

Dorsey Hager came to Tulsa from California in the fall of 1914 and later entered into partnership with Mowry Bates. Mr. Hager mapped the block of acreage owned by Bert Garber and others now occupied by the Garber field for the Chanute Refining Company. The Sinclair Oil & Gas Company drilled the discovery well. The detail work was done by Ben C. Belt and Huntsman Haworth. Dilworth S. Hager, in the employ of Hager and Bates, discovered the Virgil field, Kansas. Dorsey Hager's "Practical Oil Geology" was published in April, 1915, and has passed through several editions.

Carl D. Smith, one of the pioneers in Oklahoma geology, began commercial work for the Roma Oil Co., in the fall of 1914, and discovered the Josey field northeast of Cushing, detailed by W. Z. Miller. Subsequently the March, Mannford, and Masham fields were opened on his geology.

The most important events of 1913 for the furtherance of petroleum geology were the organization of geological departments on August 1st, by the Gypsy Oil Co., under M. J. Munn, and by the Empire Gas and Fuel Co., under Everett Carpenter. Mr. Munn had already engaged Jerry Newby and R. E. Garrett and soon had a large staff mapping surface structure. They ran elevations of section corners and important outcrops with planetables and mapped detailed structure with aneroid barometers. Mr. Munn had the good fortune to recognize the dome on the Boston lease in the Osage and to delimit the Cushing field where the Gypsy secured extensive leasehold in the south end of the Drumright district. Their purchases at the first "Osage sale" were on his recommendations. His department mapped many of the folds which have since become oil fields, including the Fox field. The department expanded to 30 men in the fall of 1914, and their work became the incentive for many Oklahoma oil companies to employ geologists in 1915. Among the earlier employees of the Gypsy were J. J. Victor, Frank Bryan, Harry F. Wright, and A. P. Wright.

The Empire Gas and Fuel Co. began planetable work in Kansas in 1913. Discovery of oil at Augusta in June, 1914, and at ElDorado in 1915, resulted from this mapping. The enormous holdings of the Empire Gas and Fuel Company on this anticline led to too great enthusiasm regarding the limitations of geology and the geological department grew by leaps and bounds to over 250 members, including 100 geologists, in 1917, scattered throughout the Mid-Continent region. This was the largest group of geologists ever brought together under one organization. Colleges and universities were combed of their graduating classes for geological students and planetable mapping was taught in training camps. Among the contributions to petroleum geology made by this department, as well as impressing oil operators with the importance of geology, were the establishment of a separate department for subsurface work with microscopic study of drill cuttings and research pertaining to petroleum largely under the direction of A. W. McCoy. Mr. McCoy is credited with the discovery of the South Duncan field in 1919. The sudden growth of this enormous organization with inexperienced and inadequately supervised men led to the completion of an enormous amount of reconnaissance mapping, much of which was done over again in later years. The hundreds of young men trained at the expense of the Empire were ultimately scattered in consulting work and throughout the many companies which now employ geologists.

Geologists came to Oklahoma in great numbers in 1914 and subsequent years, and it is impossible to mention individuals in the subsequent history. Of greater importance is their role in the discovery of oil, and this phase of geological work and the evolution of geological thought is taken up chronologically in the following pages.

RELATION OF GEOLOGY TO OIL PRODUCTION

Geology can be said to have been recognized by Mid-Continent operators as an aid to the discovery and development of new fields during the year 1913. At this time the principal oil fields were Glenn Pool and the "shallow" fields of Washington, Nowata, Tulsa, Muskogee and Okmulgee counties and along the eastern line of Osage County. This production was almost entirely from broad sand lenses—sheet sands—in which petroleum accumulation depended on the character and extent of the reservoir rock and not on geological structure either at the surface or underground; in fact, the productive sands near the base of the Pennsylvanian are locally absent from the summit of anticlines, especially where the sand rests almost directly in contact with the disconformable surface of the "Mississippi lime."

The Cushing field was discovered in March, 1912, without the aid of geology, on a very large surface and subsurface anticline embracing subsidiary domes and saddles. Development of the field was very active during 1913, and by August the producing area was nine miles long and three miles wide. The Boston pool in the Osage north of Cleveland was developed in the fall of the same year by the Gypsy Oil Company, and the discovery well was found to have been located by chance on a surface anticline. Geologists were able to predict the limits of production of Cushing, the Boston pool, and the Kennedy and Springer pool (discovered on geological work by W. S. and R. E. Vandruff) west of Hominy in the Osage and by so doing gained the confidence of the oil operators. The structure of these fields was taken as the type to be sought elsewhere, and as surface work was carried on from Cushing as a center many small domes and anticlines since productive were found in Osage County, a few were found west of Cushing, only one (Stroud) south of Cushing, and very few east of Cushing.

Production on the Newkirk anticline was opened in 1913 and this was the first oil field in the State discovered as the result of a published report and structure contour map. The Ponca City field was opened in 1910 without the knowledge that the discovery well was located on an anticline.

Healdton was discovered in August, 1913. Production is from thick sand lenses of Pennsylvanian age overlain by Permian red beds which gave very little clue from surface exposures to underlying structure.

The depth of producing wells had gradually increased from year to year. The Wheeler lime at Cushing, which was the deepest producing horizon in 1913, was found at a depth from 2,300 to 2,400 feet. The deepest dry hole in the State was the "California" well in the Wheeler field, drilled in 1909, to 3,612 feet.

During 1914 the development of deeper sands at Cushing which were discovered in December, 1913, and the proof by drilling that geological maps of surface outcrops delimited oil accumulation, gave further impetus to geological reconnaissance. This work was conducted largely by means of dips observed with the eye, or with hand levels, and aneroid barometers, but controlled in some cases by planetable elevations and even by planetable structure contour mapping. The Boynton field, a geological discovery, was the most active area outside of Cushing, but it was outstripped by Healdton late in the year. Oil was found at Bristow; a pumper at 3,467 feet, the record depth for Oklahoma, was completed at Blackwell as a result of geological work in the older, shallow gas field; the Ada gas field, a geological discovery, was extended; small wells were completed in the Allen pool of Pontotoc County (a sand lens) and in the Lawton pool (sand lenses on a very slight structure); Boston dome in the Osage was extended, and the Bixby field was opened by the Selby Oil & Gas Co.

In May, 1914, the Oklahoma Geological Survey published a structure contour map of the surface geology of the Cushing field prepared by Frank Buttram under the direction of D. W. Ohern and with the co-operation of M. J. Munn, J. R. Newby, and R. E. Garrett of the Gypsy Oil Co. This was the first published structure contour map of the field. The subsurface contours and the line separating oil from salt water paralleled the surface contours so closely that the operators were at once impressed with the value of geology and many of them employed geologists forthwith.

A flood of oil from Cushing, together with war conditions, reduced the price of oil to 40 cents a barrel in 1915. Healdton, with wells of 4,000 barrels initial production, helped to create the depression. Employment of geologists was always a barometer of the prosperity of the oil business. The discovery that geologists were not infallible in locating new fields together with the overproduction at Cushing, caused the first of many periodic reductions in the size of geological departments of large companies and in the amount of consulting work. After another ten years the operators became reconciled to these sudden changes from wonderful prosperity to slight profit and even loss, and stabilized their organization.

Cushing was extended over the Shamrock dome and Healdton to the southeast in 1916. The Fox field north of Healdton was opened by the Gypsy Oil Co., as a result of surface geological work; and as a result of geological mapping the Ingalls field west of Cushing was discovered by a well 3,485 feet deep, the deepest in the State. Garber structure was discovered, far in advance of production, by geological work done by Dorsey Hager, who came to Tulsa as a Consulting Geologist, in December, 1914. These developments gave another stimulus to surface geological work and structure contour

mapping with planetables and telescopic alidades became the accepted standard of work.

Until this time all of the oil produced in Oklahoma was supposed to have come from the Pennsylvanian rocks. Oil in the Permian at Garber dispelled the view held by some geologists that there was no oil in the Permian or west of a north-south line through Blackwell. The discovery of Ordovician[2] fossils at Healdton in November, 1916, when a producing well was "shot" in the oil sand, was the first proof of possible production from older rocks (although asphalt occurs in Ordovician strata in the Arbuckle Mountains) or of the complex underground structure now known as buried hills. The first use of microscopic fossils was made at this time to distinguish the Pennsylvanian from the Ordovician, and in 1917, a well at Healdton found oil several hundred feet below the stratum in which Ordovician fossils were found in this well.

Few wells in northeastern Oklahoma were carried below the "Mississippi lime" in the early days. The first producing well in what is now called the Wilcox sand (of Ordovician age) was drilled by the Eastern Oil Co., on their J. Berryhill lease in the SW. cor. NE. ¼ sec. 29, T. 17 N., R. 12 E., near the southwestern edge of Glenn Pool. It was completed Dec. 9, 1908, in sand from 2,331 to 2,369 feet, producing 120 barrels a day. For many years this sand was called "Sapulpa" or Mounds." The next Wilcox sand pool was opened by the Oklahoma Natural Gas Co., with their well No. 355, on Sept. 23, 1910, in SE. ¼ sec. 8, T. 20 N., R. 12 E., Osage County, producing 5 million cubic feet of gas a day. Oil was discovered on this lease in the Wilcox sand by the Sinclair Oil & Gas Co., on June 8, 1914.

The Tucker sand was found in the Cleveland pool by the Gypsy Oil Co., in their Brown 1, SE. cor. sec. 27., T. 21 N., R. 8 E., on April 15, 1912, and it is now known to be of Ordovician age, probably representing in part the Wilcox sand and in part the top of the underlying "Siliceous lime." Similar conditions are now known to exist in the Cushing pool where a small part of the Bartlesville sand is reworked Ordovician and where the Tucker sand is "Siliceous lime." The same is true in the Blackwell pool, discovered by Jones & Buell in the NE. cor. sec. 32, T. 29 N., R. 1 E., on Aug. 6, 1914.

A gas well, later deepened and made into an oil well, was completed by the Prairie Oil & Gas Co. in the Wilcox sand in sec. 35, T. 18 N., R. 12 E., in February, 1913. The Bixby field was opened by the Selby Oil & Gas Co. in the Wilcox sand on January 12, 1914, by an oil well in sec. 4, T. 16 N., R. 13 E , at a depth of about 2,000

2. The first man to discover the Ordovician fossils in the Healdton field was Dr. Powers, the author of this paper. It is my understanding that this was the first time that the occurrence of oil had been associated with Ordovician rocks in the State of Oklahoma.
C. N. G.

feet. The name "Wilcox" was given to this sand from a well completed in this field in sec. 3, by H. F. Wilcox, on April 29, 1914.

Therefore, in the light of modern knowledge part of the Bartlesville sand which made Oklahoma famous throughout the world, and probably all of the Tucker is known to have been Ordovician. It is probable that over half of the ultimate production of Kansas and Oklahoma will come from Ordovician strata.

One of the milestones in the development of petroleum geology was the organization by Charles H. Taylor and E. L. DeGolyer then living at Norman, and J. Elmer Thomas then at Tulsa, of geologists into a group which later became the American Association of Petroleum Geologists. The first meeting was held at Norman in January, 1916. In 1926 the membership was about 1,700.

By 1917 the surface geology of northeastern Oklahoma had been investigated in more or less detail by a number of oil companies and consulting geologists. No more productive anticlines like Cushing were found and the history of the old fields, where accumulation of oil had little relation to the geological structure of rocks at the surface, had been forgotten. Geologists unfortunately decided that all the oil in Oklahoma should underlie surface anticlines; the supply of anticlines was rapidly giving out, hence a shortage of oil was imminent. The cry of "wolf, wolf" was raised all too soon. However, the estimation of petroleum reserves, both to conserve oil supplies and for taxation and valuation purposes became one of the fields into which geologists ventured. Estimation of natural reserves is a project which appeals to scientists who, in turn, are pessimists. Hence, the periodical warnings of the exhaustion of oil supplies in the United States, and especially in Oklahoma have proved a source of mirth to the oil operators who are necessarily gamblers in future hopes and therefore optimists.

Underground geology, already an important factor in oil development in California, became of increasing importance in Oklahoma about 1917, as an aid to both exploitation and exploration. Logs of wells in the days of Glenn Pool were principally sand records. With the advent of geology they became complete, but the drillers were inclined to make the logs of wildcat wells read like those of the oil field with which they were familiar. Samples of cuttings were not taken, preserved and studied until about 1924.

Logs of wells were plotted on a scale of 100 feet to 1 inch of graphic well log strips which were standardized by the U. S. Geological Survey prior to 1904. Correlations in northeastern Oklahoma were based in large part on the Oswego and "Pink" lime until the search for Ordovician production, about 1923, showed that these markers gave little clue to structure in the Ordovician except in a small area around Tulsa.

Booch sand production in the Okmulgee-Beggs district during this period was seldom related to surface structure and therefore the geologists were not notably successful there until 1919. The Youngstown pool, on an anticline, was discovered in 1917 in the Dutcher sand. Billings was opened in 1917 as a result of surface geological work and both Garber and Blackwell were extended. Drilling in the Osage progressed slowly owing to the nature of the leases. Although the first "Osage sale" was held Nov. 11, 1912, the third Osage sale, April 30, 1916, was the first to attract attention. Surface structure was found to reflect subsurface structure and oil accumulation in the Osage west of Range 11. Mississippian and Ordovician production were obtained in 1917 in northern Oklahoma, but not recognized as such and most wildcat wells stopped in the top of the "Mississippi lime."

In 1917 the U. S. Geological Survey published a structure contour map of the surface geology of the Bristow area in Creek County by A. E. Fath, which led to considerable drilling in the favorable areas and to the discovery of oil. In 1917 and 1918 the U. S. Geological Survey mapped the surface geology of Osage County, the maps being published in 1918 and in subsequent years. Until their publication the tracts offered for sale at "Osage sales" were re-examined by geologists for each oil company prior to the sale, but subsequently only the tracts which appeared to be located favorably with respect to structure were examined. The detailed structure contour maps of surface geology included in this bulletin (No. 686) cover the largest area yet published in any report.

Little commercial work was done in 1918 owing to the war. Attention was called to Stephens County, west of Healdton, by wildcat producers at Velma and at Walters (both on surface anticlines and geological discoveries) and the following year the South Duncan field was opened because of combined surface and subsurface geological work. Hewitt, the second largest field in southern Oklahoma, was opened early in 1919 as a result of geological mapping done in 1916 by Wm. J. Millard for the Producers Oil Co. (The Texas Co.). A new Skinner sand pool west of Cushing, the March pool, was also opened on a surface nose mapped by Carl D. Smith.

Discovery of the Wilcox sand, of Ordovician age, in 1918-19 in Okmulgee and Creek counties, was the greatest stimulus geology ever had in Oklahoma, because this production with the exception of a few pools in the southeastern Osage, is invariably on Ordovician anticlines, and conversely almost all anticlines within the area of Ordovician production yield oil. Subsequent developments, as summarized by Luther H. White in 1926, show that the Ordovician formations were uplifted on the northeast and truncated before the deposition of the Chattanooga shale and that production formerly called "Wilcox" may come from one of several formations or unconformities. Also, most of the producing areas (and anticlines) except Tonkawa, Depew, Wewoka, and Seminole are exceedingly small and seldom exceed 80 acres in extent. Subsurface work, based on records of wells which have reached the Ordovician, has now (1926) proved to be the only satisfactory method of discovering these fields. In this work the Riverland Company, with geology by J. L. Gartner, has been most successful.

Accidental discovery of Wilcox pools in 1919, especially by the Wilcox Oil & Gas Co., showed that some underlie gentle anticlinal folds called noses. It became evident that much of the surface mapping previously done in search of anticlines with closure was inadequate to locate noses and therefore the oil companies which employed geologists undertook to remap in great detail with planetable and telescopic alidades all that portion of northeastern Oklahoma which was considered favorable for Wilcox production (without regard to existing shallower production) or which was in advance of production. This detailed mapping was completed in 1925 by most of the large companies as far west as the outcrops were considered reliable. Since then surface work has practically ceased.

Geological work in 1919 and 1920 made a great impression with the operators. Hewitt, March pool, Phillipsville (and other Wilcox pools near Beggs), Ponca City field deep sand, and several Wilcox pools in the Osage were the centers of drilling activity in 1920. Also the Deaner pool, opened by random drilling, proved to be an a surface nose and subsurface anticline.

Burbank, however, proved to be the outstanding discovery of 1920. Up to this time several large anticlines in the western Osage had yielded little oil and the two faint anticlinal folds beneath which Burbank was developed did not attract operators or geologists when leases on them were sold at an Osage sale. The discovery well in the western part of the field, drilled by the Kay Co. Gas Co., (Marland interests), produced gas before striking oil, and later the Carter Oil Co. discovery, now in the eastern part of the field, was a small well. This field spread slowly because of leasing conditions until 1926 when it was practically defined. No one suspected in 1920 that accumulation depended on a sheet sand and that production would be poorest beneath the surface folds because they reflected subsurface folds, once hills, over which little sand was deposited. Burbank production is from a sand equivalent to the Bartlesville sand and is like the old fields, Chelsea, Delaware, Bird Creek and Glenn Pool, yet more prolific. At the close of 1921, 117 oil wells and not a dry hole had been drilled in Burbank. In 1926 there were about 1,700 oil wells.

Dutcher sand production was discovered near Bristow in 1920 and the Continental, Slick and other prolific fields were developed

in the two subsequent years. The Deaner field, near Henryetta, also produces oil from the Dutcher. This horizon is near the base of the Pennsylvanian. One or more lenticular sands are usually found at this horizon, and their distribution and thickness are comparable to the vagaries of the Glenn sand. Paleogeography at the time of deposition rather than subsequent structure is the controlling factor of accumulation in the Bristow district and the largest wells are found between rather than on the low anticlines (buried hills) mapped on the base of the sand. The failure of geologists to predict or to delimit Dutcher sand production detracted from the success which they achieved elsewhere.

Geology added laurels in 1921. The Lyons and Quinn pools, near the Deaner field and in the Lyons sand, proved to be on surface noses which could be discovered only on detailed mapping. They established that many, but not all surface noses, overlie anticlines at a depth of over 2,500 feet. Later it became evident that folds in the Ordovician gradually fade out in overlying strata roughly in proportion to the thickness of the overburden so that there may be no surface reflection. Many other factors complicate this problem.

The Lyons, or Lyons-Quinn sand was first thought to belong to the Dutcher series of the Morrow formation, but was later proved to underlie the Pitkin limestone and to be of Mississippian age and equivalent to the Papoose and Cromwell sands.

Tonkawa was discovered, partly on surface work and partly on subsurface work, largely at the instigation of the Marland interests. The Tonkawa (Stalnaker) sand proved the following year to be only one of about seven producing horizons and the discovery well was on the edge of the field. The big development came after 1922.

Oil was discovered in the Hunton limestone of Siluro-Devonian age near Beede and Maud in the fall of 1921, but no profitable production was found in this horizon until at Wewoka in 1924-25.

Robberson, the first field northwest of and close to the Arbuckle Mountains, was discovered by the Magnolia Petroleum Co., on geology by Pierce Larkin. Production in paying quantities from Permian red beds is known only here, at Garber, and at Wheeler, but in each of these fields the oil may have arisen from lower horizons. Deeper drilling in 1922 revealed a buried Ordovician hill beneath Robberson with oil in the limestone.

Developments in 1922 had no material effect on the relationship of geology to production. Dutcher sand gushers near Bristow in the Continental pool, Prue sand pools southwest of Bristow (Tps. 14-15 N., R. 8 E.), and Wilcox sand and "Siliceous lime" fields

scattered over several counties, were the new discoveries. Subsurface work gained steadily in importance, and attention began to be paid by means of distinguishing producing horizons: microfossils, heavy minerals, size and shape of grains and chemical composition of contained waters.

Diamond drilling to locate surface structure came into prominence in 1923 when the Marland interests delimited the northern and highest part of the Tonkawa field. Core drilling was first tried in the State on the Chilocco Indian Reservation in 1919. The remarkable financial reward at Tonkawa which followed structure drilling led to the introduction of many drills and to the discovery in 1924 of the Hubbard, Thomas, North and South Braman, and Mehan fields in Oklahoma and others in Kansas.

Bristow was again the center of new development in 1923 and the geologists did not play as important a part in this activity as in opening "Wilcox" domes. The Ordovician was found productive at Robberson and Hewitt but this buried geology proved as difficult of interpretation as that of the Healdton Ordovician.

Production spread southwestward from Okmulgee into the area considered to be devoid of recognized oil sands, but this activity was started in spite of rather than in accordance with geological advice. The Smith pool at Wewoka was discovered by random drilling on a bending of surface structure contours so faint that it can scarcely be found on the most detailed maps. Production ultimately spread westward to the well-known surface folds south of Wewoka, but the several low domes on the Smith sand of Mississippian age cannot be reconciled with structure at the surface, 3,200 feet above. The Wilcox sand discoveries in 1926 starting again by accident and in a local syncline on the Smith sands proved that there is a pronounced discordance of dip at the top of the Hunton and that the structure on the Wilcox sand at 4,100 feet is not closely related to that on the Smith sand.

The other development in 1923 toward the southwest was the Cromwell field, started by the Cosden Oil & Gas Co's. gas well located because of a broad, long anticlinal nose and by an oil well located on the same nose and drilled by J. I. Cromwell. This field was developed in 1924 and was outlined by drilling because predictions more than a quarter mile in advance of drilling could not be made by geological work with any assurance of success.

Burbank was another example of the impossibility of predicting the limits or the size of production even with the aid of complete records because of rapid changes of sand thickness.

In 1924 Papoose, opened without regard to faint bends in surface structure contour maps, was added to the list of fields south of

Okemah. The axis of this field, east-west, was also at odds with geological predictions.

The Wilcox sand again came to the rescue of geological prognostications. Stroud was opened on a well-known surface anticline and the discovery well reached the Wilcox sand only because of paleontological determination of the age of the cuttings at the time the well was to have been abandoned. Several other Wilcox fields were opened in the Osage and elsewhere. Wilcox sand was discovered at Tonkawa and this became the wonder field of the State with more producing sands and greater production per acre than any other field.

Micropaleontology became an integral part of the oil business in 1924. Determinations of the age of cuttings and the correlation of sands became a necessary adjunct to most oil companies during this and the following year. Lithology and heavy minerals are also used in coordination with fossil evidence. This work has brought about a reorganization of scouting activities whereby scouts furnish samples and logs of drilling wells each week instead of merely the depth. In 1926 samples were being collected from practically every wildcat well in Oklahoma, Kansas and Texas. Moreover, the drillers have been given more or less instruction by oil companies in the distinguishing characteristics of formations—some companies have even taken microscopes on the derrick floors to interest the drillers in making accurate well logs. As the search for oil becomes more intensive the systems for finding and recovering oil become more elaborate.

The decadence of surface geological work marked the year 1925. Development southwest of Okemah had shown very faint connection of subsurface with surface structure. Farther west the bendings in the surface structure contours were so faint that the absence of an anticlinal bend did not condemn the possibility of oil beneath, and the presence of such bends gave faint assurance that there might be an anticline beneath. West of Cushing and Stroud the Davenport field was brought in on a surface nose, but the surface geology gave no indication of the limits of production and some of the best wells were in the surface syncline. Surface geology is proportionally more difficult west of the present oil fields because of less and less satisfactory exposures.

Geophysical work, introduced in Texas in 1923, to find salt domes, was started in Oklahoma in 1921. While no drilling to the close of 1926 on geophysical evidence of anticlinal structure has been productive of oil it is certain that some of these methods, and probably the seismograph, will be an important adjunct to new discoveries in the future.

Garber was the outstanding field of 1925. Located by surface geology in 1916 this field produced from many sands in the Permian and Pennsylvanian. The first deep test, by the Sinclair Oil & Gas Co., found a gusher in the Ordovician and led to redrilling of the field.

Core-drill structure during the year led to the opening of the Mehan and Braman Townsite fields. About 25 diamond drills were in use and the entire area from Enid to Ponca City was so well covered by drilling on every section corner that it became a problem to find sufficient room in which to look for favorable structure. Core-drilling in 1926 averaged a depth of about 400 feet and new, heavier drills were being purchased to go over 750 feet in search of structure—a remarkable change from the days of surface anticlines in 1917.

Developments during 1926 have been largely in the Wewoka-Seminole-Shawnee area where a structural plateau in the Ordovician rocks has been discovered beneath Pennsylvanian strata which dip steeply (100 feet to the mile, or 1 degree) to the west. A pronounced unconformity has been found at the base of the Pennsylvanian and above the Cromwell sand horizon which is of Mississippian age, and this unconformity is difficult to detect except by microscopic examination of cuttings because of the almost continuous shale section. Another unconformity is marked by the truncated upper surface of the Hunton limestone (Devonian, in part) below the Mississippian.

Wewoka and Seminole were the most important fields of the year because of gushers in the Wilcox sand. Discovery of the former field in the Smith and later in the Wilcox sand was accidental as stated above, but Seminole was discovered as a result of surface geological work in an area of pronounced folding and faulting with local reverse dips. The detailed structure below the unconformity on the top of the Hunton is not reflected in the structures at the surface, but of the two highest domes first developed in the Ordovician, one underlies a pronounced nose and the other a faulted anticline at the surface. Subsurface work must accompany and follow the drill and the extent of Wilcox production in this general area can only be predicted now (October, 1926) as covering a far greater area than prophesied by most operators, and rivaling if not surpassing Cushing in productivity.

The depth of the Wilcox sand in the Wewoka, Seminole, Earlsboro, and nearby fields is about 4,100 feet, in the Tonkawa field about 4,000 feet. The deepest well in the state is over 5,700 feet and is being drilled for the Wilcox sand. This indicates the depth at which production will be sought during the next few years and also the fact that Wilcox sand, or preferably "Siliceous lime," tests are required to condemn an area.

Other developments have been the discovery of Wilcox production in the Ripley gas field and in the Braman fields. Faulting

and truncation of the older rocks in the Braman fields have been found to play a very important part in oil accumulation and to emphasize the magnitude and extent of deformation in the older Paleozoic rocks as revealed by drilling in the Seminole-Wewoka-Ada area.

Evolution of methods of finding oil and evolution of geologic thought has brought a closer cooperation in 1926 between land and geological departments, with local resident geologists and land men ready to take advantage of any new subsurface determination or changes in movements of diamond drills or geophysical parties. Even the New York Stock Exchange was affected in September 1926 by predictions of new wells in the Seminole field based on examination of well cuttings and subsurface correlations. Developments at Artesia, New Mexico; Amarillo, Big Lake, and McCamey, Texas, have shown the necessity of regional plays like those in the Oklahoma Panhandle. The lack of favorable structure and even of outcrops at the surface and the necessary generalization of underground information in advance of new fields are causing oil companies to resort to checkerboarding on "hunches" as in the days before geology, except that the geologists are now assigned to the task of making the "hunches." It seems but a step back to the "oil lines" which the Pennsylvania and West Virginia operators were following in the '80s. But this step will never come because geophysics will soon come to the aid of subsurface work and will point to some of the buried hills and ridges which still retain untold stores of oil beneath the Oklahoma prairies.

SUMMARY

In recapitulation, Mr. Goodrich was the first petroleum geologist to settle in Oklahoma in 1903, when oil was unknown between Tulsa and Corsicana. Much of the subsequent work has resulted from the stimulus of a geological department at the State University and of a State Geological Survey following the footsteps of the Federal Survey. Most of the first work was done in the area of folded rocks shown on published geological and topographic maps of the Federal Survey and this area has up to the present time yielded gas only. The petroleum geologists did not recognize the significance of low folds in very gently dipping rocks until after the discovery of Cushing which was largely by accident. The successful delimination of Cushing and the discovery of oil on other anticlines in northeastern Oklahoma brought recognition to geology as a means of locating oil, but this recognition had to await Cushing because the older fields were on sand lenses on homoclinal structure and the sands do not underlie the anticlines. Oil seepages had less to do with oil development than in almost any other part of the world, because oil seepages are practically confined to the outcrop

of the so-called Bartlesville sand in southwestern Missouri and to certain sandstones in southern Oklahoma.

Geological departments of oil companies multiplied rapidly in the wake of the success by the Gypsy and Empire companies and lease brokers soon learned the desirability of having "favorable structure" on their leasehold. Consulting geologists between the fall of 1913 and 1918 were in great demand. Personal visits of Chief Geologists to colleges and universities in search of new employees were the rule from 1915 to 1918, but since then the supply has equalled the demand except in 1919-1920 soon after the war. The greatest number engaged in strictly geological work in Oklahoma attained a maximum of about 200 in 1923-24.

Surface mapping has always predominated in Oklahoma and the planetable with telescopic alidade has been used since it was introduced by Mr. McCrary in 1913. Reconnaissance by means of observed dips has not been fruitful since 1916 because the consipicuous anticlines were already producing or solidly leased. Aneroids have always been used to some extent.

Subsurface mapping of oil fields was introduced by the U. S. Geological Survey in maps of Healdton in 1915. Usefulness of the geologist in developing oil fields was recognized by oil companies as early as 1914 but not fully appreciated until 1917 or later. The great impetus to subsurface work was the recognition of the Ordovician as a producing horizon, largely because of the work of Fritz Aurin, Frank C. Greene, Luther H. White, G. C. Clark, and E. A. Trager. The report of this work was published in 1921. Beginning in 1908 pools were discovered in and below the "Mississippi lime," but, with the exception of the deep sands at Healdton, all the production was thought, until 1920, to come from the Pennsylvanian or Mississippian. The Wilcox sand was proved in 1921 by fossil evidence in overlying strata to be Ordovician. This led to subsurface mapping of the entire producing area of Oklahoma and Kansas. This type of geological work has been very successful because Ordovician production is confined to anticlines and domes in contrast to Pennsylvanian and Mississippian production which in many areas is not controlled by anticlinal folding. The importance of subsurface relative to surface work has increased steadily because developments have spread past the limits of reliable outcrops. Structure core drilling with diamond drills and geophysical work now supplement, and even supplant, surface mapping in advance of wildcatting.

The number of petroleum geologists has increased fourfold since 1914. The enormous growth has been due to the increase in the number of individuals and companies giving steady employment to geologists, and also to the number of men trained as geologists

who are occupied in other branches of the petroleum industry. The rate of increase will be much slower in the future and the percentage of men not engaged strictly in geological work will mount rapidy. When Oklahoma production decreases the number engaged in strictly geological work in the state will decrease slowly, but surely, and statistics might show an actual decrease in the past year. There will be a marked increase in the number of geologists engaged in foreign work, but the heyday of petroleum geology in Oklahoma was in 1919-20 when the price of oil was $3.50 and careful remapping of Mid-Continent surface geology in search for very faint and heretofore unrecognized favorable types of structure was in progress.