

PETROLEUM GEOLOGY IN THE UNITED STATES GEOLOGICAL SURVEY¹

HUGH D. MISER

U. S. Geological Survey, Washington 25, D. C.

The drilling of wells in the United States for natural gas began in 1821 in New York and for crude petroleum in 1859 in Pennsylvania. Oil-well drilling spread rapidly over Pennsylvania, West Virginia, Ohio, New York, and Ontario after 1859. Large-scale commercial production and marketing of natural gas began in 1878 when the country's first big gas well was completed in Pennsylvania; and they spread from that State to Ohio and West Virginia in 1884, Illinois in 1885, and Indiana in 1886.

These areas that saw the first commercial production of oil and gas were also to witness the birth and growth of petroleum geology. The early development of petroleum geology was modest and at times irregular, but full stature was attained by it late in the nineteenth century through the contributions of Edward Orton of Ohio and I. C. White of West Virginia. The potentialities of this mature youth were not fully appreciated until 1915 by its parent, the petroleum industry. At that time it was put to work, with all its energy, to guide exploration for new oil and gas fields. The incentive for this full utilization of petroleum geology was the growing demand, early in the twentieth century, of automobile owners, for gasoline to run the mounting number of automobiles.

In the history of our Nation and in the lives of our people our petroleum and natural gas have played a leading role. They have contributed to our welfare and industrial progress; they carried our armed forces to victory in World Wars I and II; and they provide assurance for our country's future welfare and security.

The Geological Survey was founded in 1879, 20 years after the drilling of the Drake well. It directed its first attention to the oil and gas resources of the United States in the late eighties and early nineties when it published reports on petroleum and natural gas in Ohio and Indiana. A continued and intensive program of oil and gas work was begun by the Survey about 1900, and an administrative mineral fuels unit was established in 1908. M. R. Campbell, the first Chief of the unit, was followed successively by David White, K. C. Heald, W. T. Thom, Jr., the present speaker, and C. H. Dane.

Campbell, like other pioneer oil geologists, Orton, J. S. Newberry, E. B. Andrews, and John A. Bownocker, was an Ohioan. He received his geologic training under Orton in Columbus. Other Ohioans, besides Campbell, to join the U. S. Geological Survey and become leaders include:

C. Willard Hayes, who was Chief Geologist from 1902 to 1911.

W. C. Mendenhall who was in charge of ground water investigations of the United States, 1907-10; Chief of the land classification board, 1910-20; Chief Geologist, 1922-31; and Director, 1931-43.

Another Ohioan in Washington is Miss Pearl F. Zeigen, who has been my faithful secretary for the past 20 years.

The first report on the geology of petroleum to be published by the U. S. Geological Survey was by Edward Orton. This report on "The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana" was published in 1889 in the Survey's Eighth Annual Report. It followed by several years the

¹ Published with the permission of the Director of the U. S. Geological Survey. This paper was presented as one of the Bownocker Lectures at The Ohio State University on January 20, 1948, and as one of the Grant Memorial Lectures at Northwestern University on March 11, 1948.

direction of Orton's interest to the subject of petroleum geology and was one of many reports that he published on the subject. One of these pioneer papers printed in 1890 was the first one on petroleum geology to be published by the Geological Society of America. At that time Orton and Israel C. White, State Geologist of West Virginia were the foremost authorities on the subject. In the discussion of Orton's paper in the Bulletin of the Geological Society of America, W J McGee, of the United States Geological Survey, paid the following tribute to the work of these two men:

"But within the past three years the laws governing the origin, distribution, and pressure of rock gas have become as well known as are the laws governing artesian water supply; so that today the geologist prognosticates rock gas nearly if not quite as definitely and certainly as he prognosticates artesian water; and it is not only just to our associates and to American science to say that this great advance in geologic science was due almost wholly to two of our fellows—to Professor Orton, the author of the communication before us, and to professor White who has already spoken upon it. To these men we are indebted for this unparalleled stride in American geology."

Orton was the first to publish consistent conclusions on the origin and accumulation of petroleum and on the relation of artesian pressure to oil and gas pressures. Also he brought out the fact that the porosity of the Trenton is dependent on the extent of dolomitization, and that this factor largely governs location of the productive areas scattered over the great Cincinnati arch. He also introduced in the United States in 1888 and 1889 the use of structure contours for showing oil field structure. By means of the contours and shading between them he showed the topography of the Trenton limestone in western Ohio and eastern Indiana.

White published in 1885 his epochal statement on the anticlinal theory of oil accumulation and on his practical application of it. Other geologists including Hunt (1861), Rogers (1860), Logan (1844), and Andrews (1861), had observed the association of oil accumulations with anticlinal axes. Their opinions appear to have little influence on oil exploration and they were strongly opposed by J. P. Lesley. So important was White's statement that Orton proclaimed that his applications of the theory mark a new period in our study of the geology of oil and gas.

It was under Hayes' guidance as Chief Geologist of the U. S. Geological Survey that the refinements of detailed stratigraphic and structural studies were first to be applied in a large way, beginning about 1900. Mining engineers and geologists had, of course, applied similar methods to small areas before Hayes introduced them into the National Survey. It remained for him, however, to show that detailed structures could be worked out over large areas without an inordinate expenditure of time and money. It was his success in the locating of oil pools that led to his being called later to assume charge of the geological work of the Mexican Eagle Oil Co. in Mexico.

About 1900 the U. S. Geological Survey began the examination of a number of oil-producing areas in the Appalachian States, particularly Ohio and Pennsylvania, and structure contours were an essential feature. These reports did much to popularize the use of such contours.

The first of these reports to show the detailed structure of an oil-producing sand by means of structure contours was Bulletin 198, "The Berea grit oil sand in the Cadiz quadrangle, Ohio," by W. T. Griswold. This quadrangle was surveyed in 1901 by Griswold, who introduced the plane table for geologic mapping in connection with his mapping of the topography of the quadrangle.

Industry's adoption of geology as a guide to the study of oil and gas deposits in 1915 was based on the reports of the few geologists in company employment and on reports of the U. S. Geological Survey and various State Surveys, notably the Oklahoma and Kansas Surveys and the California State Mining Bureau.

These reports demonstrated clearly, for many areas, the relation of oil and gas accumulations to anticlinal structure. As a consequence, the early part of the present century witnessed the beginning of a vigorous search for anticlines as drilling sites for oil and gas wells. Also, the Geological Survey made a notable contribution to the development of the oil and gas industries through the training of petroleum geologists who subsequently resigned from the Survey between 1908 and 1925 to join large geologic staffs that were being organized by the oil companies. These geologists, who were thus Geological Survey graduates, became a significant proportion of the leaders in a world-wide search for petroleum.

The oil work of the Geological Survey was greatly accelerated during World War I and again in World War II. In World War I the Geological Survey responded to the imperative need for increasing to the utmost the petroleum supply of the United States, and it largely concentrated its investigations of oil fields in the most promising undeveloped territory, such as Wyoming, and the mid-Continent-Texas region, and especially in the Osage Reservation in Oklahoma. The Osage Reservation demanded particular attention at the time for the following reasons: (1) it contained a great acreage of unleased oil lands; (2) the productivity of the developed areas was high and well sustained; (3) anticlines and domes are numerous in the greater part of the area and the developments and tests indicated that most of the structurally favorable folds would yield oil; and (4) the Office of Indian Affairs, which administers the lands held in common by the Osage Indians, was then offering leases of hundreds of quarter sections to openly competitive bidders on advertised dates. Altogether some 45 geologists and instrument men took part in this investigation of the Osage Reservation under the supervision of K. C. Heald. The long list of their names is most impressive for it is a roster of present-day leaders, of whom two, W. B. Emery and E. M. Spieker, now live in Ohio. To these geologists and instrument men, David White, Chief Geologist, paid the following tribute:

"The field work, which included plane-table mapping with telescopic alidade under many hardships in addition to those of the severe winter (of 1917-18) was carried forward with splendid team work and with gallant and indefatigable emulation. In recording his admiration for the esprit and high standard of this War Work done by geologists in professional civil service, the writer believes he expresses the appreciation not only of the Geological Survey but of the operators as well."

The World War II period of acceleration of oil and gas work began in 1943 and is still in progress; it exceeds in magnitude any oil and gas work heretofore undertaken by the Survey. The number of geologists employed in the Fuels Section in recent years has reached a maximum of about 100 and the number of clerks, draftsmen, and other employees has reached a top figure of about 30.

The purposes of the Survey's present oil and gas work do not differ from those that have guided similar work by the Geological Survey at all other times during the past 50 years. On the other hand, as the methods and techniques of industry have changed during the past 50 years, the nature of the Survey's work has changed.

The mapping of local structural features has been stressed less and less by the Geological Survey and greater emphasis has been placed on regional geologic problems, although some effort is necessarily being directed specifically to the acquisition of information essential for the administration of laws relating to the leasing of public lands for oil and gas development.

The type of work that is being emphasized in recent years is regional geology involving both subsurface and surface stratigraphy in large areas, such as basins or similar geologic provinces. Studies are being devoted primarily to the accumulation of data for the preparation of maps and stratigraphic sections showing such features as the thickness and change in facies of oil-producing formations, the margins of producing or possible producing zones, and the relations and extent of lenticular sands. These studies have as their objective the delimitation of

broad areas that are favorable for exploration. The determination of local structural features, whether by surface, subsurface, or geophysical methods, is not being stressed.

In the formulation and prosecution of the present program of regional stratigraphy and structure the counsel of petroleum geologists and also State Geologists was sought. Many hundreds of petroleum geologists, the officials of numerous educational institutions, and about 24 State Geologists have provided suggestions concerning projects, methods of procedure, and other forms of cooperation and assistance. Also, the program of geologic work is being carried out with the active collaboration of the oil and gas industries, many universities, and the State Geological Surveys. This collaboration assures effective prosecution, without duplication of effort, of types of projects that yield useful results.

The present program of work has been decentralized. Nearly all the work is being done outside Washington. The field employees reside and prepare their reports at project offices. The employees in the Washington office are engaged in the administration of the program, and in the review and processing of reports for publication.

The maintenance of the project offices in the States has many advantages. The field geologists are thus located in areas conveniently near sources of information and are in close personal contact with company geologists and the officials of State Geological Surveys and universities. These contacts give opportunity for the exchange of ideas and for mutual understanding among those who are interested in common problems.

Project field headquarters are now located at the following places: New Philadelphia, Ohio; Ann Arbor, Michigan; Tallahassee, Florida; Tuscaloosa, Alabama; Tulsa, Oklahoma; Lawrence, Kansas; Denver, Colorado; Laramie, Wyoming; Billings, Montana; Albuquerque, New Mexico; and Claremont, California.

Other headquarters that have been used at different times in the past four years are Nashville, Tennessee; Oxford, Mississippi; Morgantown, West Virginia; Austin and Fort Worth, Texas; Norman, Oklahoma; Corvallis, Oregon; and Los Angeles, California.

The different parts of the United States where work by the Fuels Section has been under way during the past four years, include California, Oregon, the Rocky Mountain region from New Mexico to Montana, many States in the mid-Continent region from Texas to Michigan, the southeastern States from Mississippi to Florida, and the Appalachian region from Tennessee and Virginia to Ohio and New York. These areas cover a considerable proportion of the parts of the country that produce petroleum and natural gas or are favorable for their production.

Basic geologic data obtained by the Geological Survey in the course of its work are being made available promptly, through publications, to those directly concerned with the drilling of wells and the testing of new areas. The oil and gas investigations are so planned that useful and timely results can be published rapidly. The results are embodied in large measure in a series of preliminary maps and charts on which brief explanatory texts are printed.

The Geological Survey has printed 110 such maps and charts in its current series. More than 77,000 copies have been sold. Also, during the past 4 years, numerous articles and reports have been submitted for publication to trade and scientific journals and cooperating agencies.

Some types of the preliminary reports are on display on the walls of this auditorium. A complete display of our maps and charts, placed end to end and pasted together, would make a sheet of paper 500 feet long.

Petroleum geology in the U. S. Geological Survey is largely centered in the Fuels Section of the Geologic Branch. The work of this section is closely coordinated with the fields of other sections of the Geological Survey that deal primarily with paleontology, stratigraphy, chemistry, physics, geophysics, mineralogy, and

petrology. In fact, much of the work of these several sections, outside their collaboration with the Fuels Section, is devoted to providing basic information that is utilized by the oil and gas industries in their search for, and development of, our oil and gas resources. Thus, much of the geologic effort of the Geological Survey is related to oil and gas, either directly or indirectly.

In addition to the geologic work of the Fuels Section, some studies that are essential for the administration of the oil and gas bearing public lands are conducted by the Conservation Branch of the Survey. Moreover, intensive studies of the oil and gas resources and possibilities of Alaska have been made since 1903 by Geological Survey geologists. E. M. Spieker has participated in pioneer work in recent years in that frontier area.

The Appalachian project with headquarters at New Philadelphia, Ohio, is typical of many regional projects that were begun in 1943 to assist in the search for much needed oil and gas.

In August 1943, James F. Pepper, the chief of the party, and I made a trip through the Appalachian Basin to see what might be the consensus of geologists of the area as to the type of work that would be most useful to industry. We visited the geological surveys of Ohio, Pennsylvania, and West Virginia, and the geological societies at Charleston, West Virginia, and at Pittsburgh, Pennsylvania.

The decisions reached during this canvass were as follows:

1. Because the project was financed by Federal funds the problems should cover several States and be regional in scope.

2. No regional subsurface studies of a producing sand had ever been made in the Appalachian Basin, nor had extensive surface and subsurface studies been made of a sequence of related beds to determine in so far as possible (a) the facies changes over a broad region, (b) the source areas of the material in the beds, (c) the manner of deposition of the sediments, and (d) the paleogeography of the producing sand and related beds.

The conclusion was reached that an intensive study of a sand following the above outline would be most useful. Before a suitable sand for study could be decided upon several other definite requirements had to be met, namely,

1. The sand must be, or have been, a prolific producer of oil and gas.
2. Many hundreds of well records and locations must be readily available in the files of State organizations and private industry.
3. Since personnel would have to be trained on the job, the correlation problems of at least a part of the area must be at a minimum.

The Berea sand seemed most nearly to fulfill all of the requirements and it was selected, therefore, for intensive study.

All of the personnel of the Appalachian Project arrived by October 1943. The party at that time consisted of nine geologists, a clerk, and a draftsman. Most of the geologists were new to oil and gas geology. One geologist of the group, Gordon Rittenhouse, was a specialist in sedimentary petrography. He was assigned to Morgantown, West Virginia, where the State Geological Survey made available an exceedingly well equipped laboratory for his use.

The project quickly lined up into the following procedures:

1. Several geologists were assigned to the field to copy the many well records and locations required in the study.

2. Other geologists in the New Philadelphia office located the wells on topographic maps, plotted the well records and made a correlation of the Berea sand between wells. The thickness of the Berea sand in each well was spotted in its appropriate location and the thicknesses were drawn together by contours or isopachous lines.

The region in Ohio, Pennsylvania, West Virginia, and Kentucky, in which the Berea sand is present, was divided arbitrarily into six nearly equal areas for convenience in collecting and correlating data and for publication of the data.

The completed preliminary study of the Berea sand consisted of six preliminary maps, two of which have since been revised, a preliminary chart (No. 21) by Wallace deWitt, Jr., and a map showing the distribution of several types of Berea sand by Rittenhouse. A map (No. 5) of an older sand, the second Berea sand of Ohio, was published also.

In the study of sand in a large region, such as the Appalachian Basin, much information is acquired. A great part of the information is suitable for the study of sedimentary deposits. For instance, a side issue was a study of the areal extent and thickness of salt beds in Ohio by Pepper, a study of which, if not purely scientific, will be of use to an industry interested in obtaining salt for chemical or other purposes, to say nothing of the hilarity already induced by the coincidental association of names.

Altogether, as a result of the initial investigation of the Berea sand in Ohio, Pennsylvania, West Virginia, and Kentucky, 22 preliminary maps and articles have been published. These publications, as previously mentioned, are an outgrowth of the vast supply of information now on hand. The papers have included grain size analyses, procedural techniques, and an analysis of the paleogeography of the Greenbrier limestone by Rittenhouse.

As a result of the studies of the Berea sand, the information from all preliminary maps and other sources has been compiled into a manuscript for a professional paper. At present, this report is, in its preliminary writing, about 95 per cent complete.

The present plans of the project include an intensive study of the Clinton sand. The compilation of the preliminary Clinton data is now nearly complete and the material is now ready for study. Other work in the Appalachian Basin will include surface mapping of the Dunkirk formation of Devonian age in New York. This study, it is hoped, will determine the correlations and stratigraphic relations of the Dunkirk and Wiscoy formations from Lake Erie eastward to central New York. The results of this study will aid further in the correct interpretation of the stratigraphic relations of the formations in several quadrangles in central New York which, at the present time, are about three-fourths mapped.

It goes without saying that a project covering such a large region (approximately the size of California or of Great Britain) would be futile and its results entirely negligible if it were not for the willing and general cooperation of state surveys, oil and gas companies, and individual operators. One of the unknown factors at the start of the Appalachian Project was the extent to which all who were interested in oil and gas in the Appalachian Basin would cooperate with the Survey. Time has shown that the cooperation, interest, and generosity of all contributors have been exceeded in no other area in the United States. It must be remembered that the Appalachian Basin has no regional scouting service, and with the exception of an agency in Charleston, West Virginia, (specializing in West Virginia well records), no log service of any kind. The generosity of organizations and individuals is all the more remarkable considering the amount of time which they have given the Survey and the amount of trouble members of the Appalachian Project have imposed upon them in obtaining well records. For example, the Appalachian project, in copying well records at the Ohio Fuel Gas Company, totaled a full year's working time for one person. To the Geological Department of the Ohio Fuel Gas Company and to its parent company, the Columbia system, and other subsidiary groups, the Appalachian Project owes a deep debt of gratitude. In Ohio the Appalachian project owes gratitude to the State Geological Survey and its members, past and present,—particularly to Mr. Wilber Stout, ex-State Geologist, to Mr. R. E. Lamborn, Assistant State Geologist, to Dr. George W. White, recent State Geologist, and to Mr. John H. Melvin, the present State Geologist. These companies and individuals and also the Pure Oil Company of Newark, Ohio, and the independent producers of Marietta, Cambridge, and Canton, Ohio,

are only a few of the many in Ohio, Pennsylvania, West Virginia, and Kentucky who have been of great assistance to the project, for without their assistance the record of the Appalachian project would be entirely barren of results.

The United States has for many years produced about three-fifths of the world's petroleum. Continuation of this rapid rate of drawing on our supplies will hasten the approach of the day when the discovery rate of petroleum will decline to the point where our crude petroleum supplies will not meet fully our needs. Adequate future supplies of petroleum products must at all times be assured for the security and welfare of the Nation. Sources of these products are not alone the crude petroleum in this and other countries but also substitute sources which include oil shale, coal, oil-saturated sands, and natural gas. The domestic deposits of these substitutes sources are large, as established by studies of the U. S. Geological Survey, State agencies, and industry, and they are capable of providing ample petroleum products for fully 1,000 years. The Nation must be equipped with fuller and more adequate information than now available concerning the extent, character, and reserves of these substitute sources and concerning processes of large-scale recoveries of petroleum products from them. This is necessary so that they may be utilized promptly when the Nation is required to turn to them to augment domestic and imported supplies of crude petroleum.
