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THE NATION AND PETROLEUM GEOLOGY TO-DAY[1]

By HUGH D. MISER

U. S. GEOLOGICAL SURVEY

OUR nation is entrusted with a rich heritage of abundant petroleum. The annual output of this essential mineral fuel may be expressed in barrels and dollars, but to offer a fitting measure of its importance would require an appraisal of the service of petroleum in terms of human welfare and progress.

Chief among the many uses of petroleum is the generation of power. Such power drives 30 million motor vehicles on the nation's highways, 1½ million tractors on American farms, our merchant vessels and Navy on the ocean and our planes in the air. Altogether one third the mechanical energy produced in the United States comes from petroleum. Also, crude petroleum provides the plentiful supply of lubricants that has made possible our machine age.

The modern petroleum industry dates from the drilling of the Drake well in Pennsylvania in 1859 and, although the industry now encircles the earth, our country leads in the development of the industry and it produces and consumes three fifths of the world's oil. Also, our known oil reserves are equal to those of the rest of the world.

PRODUCTION OF PETROLEUM

The value of our petroleum output for 1938 expressed in dollars is one third the value of the entire annual mineral production of the United States. The next mineral product in point of value is coal, the next is natural gas, and then follows iron. Further

[1] Address of the vice-president and chairman of the section on Geology and Geography, American Association for the Advancement of Science, Columbus, Ohio, December 27, 1939. Published by permission of the director of the Geological Survey, United States Department of the Interior.

comparison reveals that the total value of all the metallic mineral products combined for that year is two thirds the value of the oil output.

Our domestic petroleum production is obtained from about 370,000 wells in 23 states; only a small part—about 5 per cent.—of our domestic consumption is imported from other countries, and the exports are equal in volume to 16 per cent. of the domestic production in 1938.

The production of petroleum in the United States has mounted rapidly during the twentieth century, when it has been related primarily to the expansion of the motor-fuel demand. The first billion barrels of oil had been produced by 1900, 41 years after the first barrel was recovered from the Drake well, but the present year, the eightieth anniversary of the industry, has witnessed the production of the 22-billionth barrel of oil. Of the producing states, Texas ranks first, having produced a quarter of the total output of the nation's oil to the end of 1938, California ranks second, with 24 per cent. of the output, and Oklahoma is third, being credited with 21 per cent.

Relation of Geology to Petroleum Industry

During the first half century of the petroleum industry geology was utilized only to a limited extent in the finding of oil. Progress was, however, being made from time to time in the demonstration of the relation of petroleum to anticlinal structure, and by 1915 this structural relationship had been established so clearly in numerous areas that geology was then generally accepted by the industry as a valuable tool in the search for oil.

The number of geologists now serving the industry in the United States, in the employ of companies and of governmental and other institutions, and in other capacities, appears to exceed 3,000—a number somewhat larger than the number of geologists in the United States who are members of the American Association of Petroleum Geologists. Altogether 2,638 geologists living in the United States were members of this organization on March 1, 1939; and of this number, 2,064 oil geologists live in the five leading oil-producing states, Texas, California, Oklahoma, Louisiana and Kansas. To express the quantitative relation of geologists to oil, there is one geologist for each half million barrels of oil produced in those states in 1938.

Current Methods Employed in Petroleum Geology

In the solution of the geologic problems involved in the search for oil new methods of technique and new trends in the application of geology are developed and adopted from time to time by the oil industry, and old methods and practices are frequently modified or abandoned. Some of the current methods and practices employed in petroleum geology are here briefly mentioned.

Surface geologic surveys to locate favorable areas for oil by the mapping of anticlines, domes and other structural features reached their peak application between 1920 and 1925 and have thus occupied for many years a place of decreasing importance in the finding of new oil fields. Accordingly, from year to year, an increasing proportion of effort and funds is devoted to the study of subsurface geologic features that are not discernible from an examination of the exposed formations.

Core drilling for the determination of geologic structure was first employed by the petroleum industry in the United States in 1919 and is still being employed in parts of the Mid-Continent region. Also, in this and other regions a current practice is to obtain the cores of oil sands and other important beds for a study of their character and fossil content. In recent years rapid routine methods for measuring the physical characteristics of sandstone cores have been developed. The laboratory orientation of well cores by their magnetic polarity, developed in 1928, provides a rapid and inexpensive method of determining the dip of core samples that have good bedding planes and a sufficient content of heavy minerals in which polarity has been induced by the earth's magnetic field.

The microscopic examination of well cuttings was begun on a large scale in 1917, and since that time it has reached a place of fundamental importance. A special method for the study of well cuttings of limestone and dolomites that was introduced in 1924 by H. S. McQueen consists of a microscopic examination of insoluble residues that are obtained by dissolving the cuttings in hydrochloric acid.

Micropaleontology has been an integral part of the oil business in the United States since 1924, and is employed for determining the age and local and distant correlations of the rock strata.

Geophysical methods, magnetic, gravimetric, electrical and seismic, are widely used in the United States as a means for locating and mapping buried structural features. In 1924 oil companies discovered three salt domes in the Gulf coast region by geophysical methods, and since then more than 100 salt domes in the Gulf coast region and numerous other structural features from New York to California have been located by such methods and later established by drilling.

The electrical logging of drill holes was developed in 1928, and its applications have become increasingly valuable from year to year. From the records of logs obtained by this method, the nature and thickness of all oil- and water-bearing zones are determined. Also their use permits short-distance correlation of formations within oil fields and, in conjunction with lithologic and paleontologic studies of cores and cuttings, permits also long-distance regional correlations.

A method, commonly known as "soil analysis," whereby the areas of greatest concentrations of hydrocarbons in the soils are determined, is at present receiving consideration as a possible aid in the exploration for oil.

A development that is of great value not only in geologic mapping but also in other phases of the oil industry is that of airplane photography. As a result of the tremendous improvement of airplanes, cameras and photographic methods during the last several years, mapping of this kind has become an indispensable tool of the petroleum industry. Indeed, aerial photographs are useful in so many industries and governmental activities that about two thirds of the area of the United States has been so photographed.

Contribution of Petroleum Geology to General Science of Geology

Petroleum geology enjoys a wide field of opportunity for the investigation of surface and subsurface geologic features. A great store of information has been provided by the 970,000 wells drilled for oil and gas in our country, and up to the beginning of 1939, 203 wells had been drilled below 10,000 feet. The deepest well, which was completed in 1938 in the southern San Joaquin Valley, California, reached a depth of 15,004 feet. In addition the depths reached by geophysical methods exceed 30,000 feet. From the information supplied by these and other sources petroleum geology has made notable contributions to the general science of geology.

One of these contributions has been the revolutionary change in our knowledge of the geology of the salt domes in Louisiana and Texas in the last quarter of a century. Now the domes are generally regarded as intrusive plugs of salt that moved upward from bedded salt of probable late Jurassic age. As an example of an area whose tectonic map has undergone great transformation as the result of oil exploration the Gulf coastal plain may be cited, for the tectonic map of that area has been modified by the addition of such structural trends as the Mexia fault zone, the buried course of the Ouachita belt of Paleozoic rocks and the Gulf coast geosyncline.

Stratigraphy, of a refined character, has received impetus in consequence of the requirements of the oil industry for exact information concerning the thickness and character of rock strata of prospective oil regions and of areas under development. For example, petroleum geologists, in their search for structural data in western Kansas, have matched the intervals between bentonite beds in the Niobrara chalk in a way suggestive of the matching of tree rings by archeologists in dating ancient pueblos in New Mexico and Arizona.

A scientific product of an investigation by N. W. Bass and his coworkers of the shoestring sand bodies that yield petroleum in Greenwood and Butler Counties, Kansas, and Osage County, Oklahoma, is that these elongated lenticular sand bodies represent sand bars along ancient shore lines during the Pennsylvanian epoch. From data obtained in the course of the investigation maps have been prepared showing the shore lines of the ancient seas as they existed in Kansas and Oklahoma 250 million years ago.

The deep drilling for oil and gas provides not alone stratigraphic information but also structural data that permit the preparation of subsurface structure maps, both local and regional in character. In the words of R. A. Daly at the banquet of the Geological Society of America in Tulsa, Okla., on December 30, 1931, the petroleum industry has contributed the third dimension to geology.

Discovery of Other Mineral Products

The petroleum industry, in its addition of this new dimension to geology, has had an unusual opportunity to discover new deposits of other mineral products. Commercially important deposits of five mineral products thus discovered with the advent of deep drilling and search for petroleum are natural gas, helium, natural carbon dioxide, potash in New Mexico and sulfur in the coastal areas of Louisiana and Texas. The five industries centering around these may thus be regarded as quintuplets of mother petroleum in the household of the mineral industry.

Reserves and Future Supply of Petroleum

The known reserves of petroleum in the United States at the beginning of 1939 reached the highest figure in the history of the industry. The different estimates of the reserves at that time ranged from 14 to 17.5 billion barrels. Such reserves in the ground, like the stocks of petroleum held above ground, are constantly changing in quantity. They are depleted by the output of producing wells and increased by the discovery of new fields and deeper pools.

The continued discovery of new sources of supply is essential for the survival of the petroleum industry. The extent to which new sources are discovered and made to produce depends upon the payment by the consumer of prices that will permit the industry to carry the heavy and increasing expense of new exploration and maintain profits.

Much oil remains to be discovered in new fields and in deeper pools, but the exact location of these fields and the quantity of petroleum they will yield will not be known in advance of drilling. Nevertheless, their number, whatever it may be, is definitely limited, and each newly found field leaves one less to be discovered. The day when the United States will face a petroleum shortage does not now appear to be predictable. The distance to that day in the future lies not alone in the supply of oil remaining in the ground. It rests also with the geologist to continue to aid in the increasingly difficult problem of discovery, with the engineer to improve drilling technique and increase recoveries and with the chemist to continue improvements in refining practice. In part, it rests on the price that the public can pay in the future for oil products; the ability of the public to pay future prices in turn depends in part on increased efficiency in their use. In a large measure the distance to the day of petroleum shortage rests on conservation and efficiency in the discovery, development and production of our future oil fields.

Advances in science and technology affecting the discovery, recovery, refining and utilization of petroleum will undoubtedly continue. Thus far, such advances have enabled us to keep and augment supplies ahead of needs, but they afford us no assurance that the same record can be maintained indefinitely.

When a shortage of domestic crude petroleum arrives and there is a consequent rise in prices of petroleum products, substitute oil products from coal and oil shale, alcohol from farm products and gases from wood will be utilized, just as they are now used to some extent in certain countries that possess little or no oil resources. The cost of making gasoline from coal in British and German plants is probably three or four times the present cost of producing gasoline from petroleum in the United States. Concerning this subject Dr. Fieldner, of the Bureau of Mines, remarks: "These costs will be reduced by further research, but no other liquid motor fuel, whether it be from coal, oil shale, or vegetable matter, can hope to be as cheap as our present petroleum fuels." Should coal be called upon to supply the demands now met by oil and gas the coal deposits of the United States would, according to independent estimates by Dr. Fieldner and T. A. Hendricks, last about 2,000 years. These estimates are based on the assumptions that coal will be called upon to supply energy at the rate of the peak energy consumption of 1929 and also that there will be a 30 per cent. loss of coal in mining.

THE CASE AGAINST THE CELL THEORY[1]

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Modern biologists, in general, resent listening to theories; they are interested, they say, in facts only. But the organization of the present gathering and of many similar ones, all over the world, to commemorate the formulation of a *theory,* proves, on the other hand, that there is still some consideration for this form of intellectual activity. Why, then, do the biologists condemn theorization at times and honor it at other times? Is such an attitude mere inconsistency on their part? It seems, rather, that it is due to a state of mind which resulted from an apparent conflict between two evident facts: one is that theories have often been dangerous because they were held as doctrines; the other is that the elaboration of theories, at least in an implicit form, is a necessary and unavoidable procedure in any thinking. To reconcile ourselves with the situation we need only to recognize the necessity of theories but to remember also that they are dangerous tools which should be put in the hands of those only who know enough never to believe in them. The science of thinking consists in knowing how to use these tools, that is, in never admitting any theory except as a possibility. Since faith in theories has done much harm to human thought, the dangerous aspect of any theory, namely, to inspire belief, will be emphasized in the following discussion.

A theory is often considered acceptable if it is useful and if it allows one to foresee unknown facts. It is clear, however, that, in the last analysis, we require more than that from a theory; we want it to represent the truth. We are not satisfied in knowing what a thing might be, as proposed by any theory, we want to know what it actually is, and this is proposed by only one theory. When it becomes evident that a theory does not represent the truth, even if it has been useful and is still useful in the discovery of new facts, we abandon it and try a new theory which might have more chance of being the true one. In general, a theory is useful in proportion to its nearness to the truth, but there are examples of theories which have been useful for centuries and finally had to be abandoned as inadequate to explain newly discovered facts; such is the case of the old classical theory of the corpuscular nature of light. In the last analysis, then, the decision as to the acceptance or maintenance of a theory depends only on the answer to the question: Has this theory a chance of being true or not?

Let us come now to the definition of the cell theory. The statement of the fact that most living beings

[1] Address delivered to the Sigma Xi Club of Saint Louis University on April 18, 1939, at a meeting organized to commemorate the centenary of the formulation of the cell theory.