Results of Petroleum Exploration in Naval Petroleum Reserve No. 4 and adjacent areas, Alaska

by

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(Paper presented at annual convention of American Association of Petroleum Geologists, Houston, Texas, March 26, 1953. Paper also presented with impromptu minor modifications at the Fourth Alaskan Science Conference, Juneau, Alaska, October 1, 1953.)

ABSTRACT

Naval Petroleum Reserve No. 4 was established by Executive Order of the President in 1923. It is in Arctic Alaska in a treeless area that is cut off from the rest of Alaska by an east-west mountain chain, the Brooks Range. In 1923 the U.S. Geological Survey, Department of the Interior, was asked to examine and report on the area. This was done in the years 1923 through 1926, and the results were published in 1930 as Geological Survey Bulletin 815. In 1944, the U. S. Navy began an exploration program in an attempt to further evaluate the petroleum possibilities of NPR-4; in 1945 the Geological Survey was asked to participate in the geologic phase of this program.

Geologically, and to some extent topographically, the Arctic Slope of Alaska is comparable to the western interior region of Canada and the United States. The Brooks Range, composed largely of late Paleozoic rocks, is the Alaska counterpart of the Rocky Mountains. Northward from the Brooks Range the topography becomes progressively more subdued and the age of the bedrock progressively younger (Mississippian through Tertiary).

A large part of NPR-4 and adjacent areas has been or is being explored by geophysical and geologic methods. Geophysical studies include reflection, refraction, gravity, and magnetic surveys. Geologic field surveys range from reconnaissance to detailed mapping, in addition to interpretation of geologic features on aerial photographs. Cores and other rock samples are analyzed in the laboratory in Fairbanks, Alaska.

Exploratory drilling has been started in the southern foothills immediately north of the Brooks Range. To December 1952, 35 test wells and 41 core tests have been drilled on 18 structures in the coastal and northern foothills regions. Two oil fields—Simpson and Umiat—and one prospective field—Fish Creek—have been discovered. Two gas fields -- South Barrow and Gubik -- and four prospective gas fields-- Meade, Square Lake, Titaluk, and Wolf Creek--have been discovered. At South Barrow, gas is being produced for use at Barrow camp. For these fields, estimates of oil reserves range from 30 million to 100 million barrels, and estimates of gas reserves range from 370 billion to 900 billion cubic feet.

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When this paper was first considered, several months ago, Cmdr. Jensen and I had in mind a progress report on the oil exploration program in northern Alaska. A major change has been made since then; most of you know that less than three weeks ago the Secretary of the Navy reached an agreement with members of Congress to close out the northern Alaska petroleum exploration project. This action was taken with the knowledge that the exploration program was not completed and could possibly be completed in 2 or 3 years.

However, this changes the story I have to tell only from a progress to a final report. I would like now to sketch briefly the geographic and geologic setting of northern Alaska, the petroleum exploration history of the area, and finally the results to date.

I--and I'm sure many others--forget the size and expanse of the Territory of Alaska. I hesitate to mention this--but Alaska is larger than the state of Texas. However, my talk today deals with only a small part, the Arctic Slope of Alaska.

Naval Petroleum Reserve No. 4 was established by Executive Order of President Harding in February 1923. It is a treeless area of approximately 37,000 square miles, cut off from the rest of Alaska by an east-west mountain chain, the Brooks Range. The rest of northern Alaska has also been withdrawn from public entry by Public Land Order 82. It would be well to note the relationship of northern Alaska to the Alaska Highway and the northern terminus of the Alaska Railroad, both about 300 miles from Umiat.

The recent exploratory work shows that geologically and to some extent topographically the Arctic Slope of Alaska is comparable to that of the western interior of Canada and the United States. The Brooks Range represents the Alaskan counterpart of the Rocky Mountains.

The Romanzof Mountains in the eastern part of the Brooks Range include glacier-covered Mt. Michelson, 9,223 feet above sea level, the highest peak in the range. The Brooks Range province is composed of Devonian and older rocks predominantly in the southern part of the Range, and Carboniferous and Permian in the northern part. Sharp folds, overturned faulted folds, and thrust plates in imbricate arrangement characterize the structure of the mountains. The main period of deformation was early Cretaceous and Tertiary.

North of the Range are smaller isolated mountains. The peaks of limestone and thick sandstone and conglomerate, surrounded by lowlands underlain by shale, form the Southern Foothills province. This province lies in a belt of complexly infolded and faulted Carboniferous, Permian, Triassic, Jurassic, and lower Cretaceous sediments. The structure promises to be every bit as complicated as the Alberta foothills. It is possible that fields analogous to Turner Valley may be found in this area. Late Paleozoic rocks are exposed locally and are believed to

be within drillable depth in anticlinoria and thrust blocks. Devonian and Mississippian sections include dolomitic limestone. Some of the Mississippian limestones are bituminous. The Mississippian limestone which probably would be the reservoir, is lithologically much like the Rundle formation of the Alberta foothills. It contains biostromal limestone made up of debris from crinoids, bryozoans, and other forms.

The isolated mountains of the Southern Foothills give way to the north, to rolling hills and long linear ridges. The well-defined structures in the western part of NPR-4, a belt of appalachian-type folds, constitute the Northern Foothills province. It is composed of lower and upper Cretaceous sediments with generally poor reservoir characteristics. However, the oil zones of the Umiat and Simpson fields and the Fish Creek well are in these rocks. Possible reservoir beds in late Paleozoic rocks are here believed to be beyond the present practical drilling depth.

North of the foothills provinces the Arctic Slope is a flat monotonous plain marked by literally thousands of lakes. Beneath this Coastal Plain area the structure is essentially flat. At the southern edge of the Plain the basement surface is at a depth of at least 22,000 feet. North to Point Barrow the basement surface rises gradually until at the Barrow gas field it is but 2,000 feet from the surface. Test wells in the Arctic Coast area show that the thick sedimentary sequence, over 20,000 feet in the Brooks Range and Foothills province have thinned to 5,000 feet or less along the Arctic Coast. This is due to the thinning of the Mesozoic rocks and the almost complete disappearance of the late Paleozoic rocks. The Mississippian limestone appears to be gone completely. At Barrow the basement surface is overlain by Triassic beds.

In summary then we can say that, geologically, NPR-4 stretches across a depositional trough of late Paleozoic and Mesozoic rocks, bordered on the south by an east-west trending complex structural belt which gradually gives way to gentle structures in the deepest part of the trough and then essentially flat-lying beds which rise gradually to within 2,000 feet of the surface on the Barrow "high". This depositional trough also rises to the east with little change in the east-west structural trend but with interruption by the northerly swing of the eastern Brooks Range. To the west the trough continues essentially uninterrupted to the Arctic coast. However, detailed field structural studies and office photogeologic studies strongly indicate another structural pattern, which trends north-south and forms local highs. In the Foothills Province many closed structures are present but good reservoir beds are rare. The Mesozoic sandstones are largely graywackes and these are underlain by a great thickness of shale. Possible Mississippian limestone reservoirs are apparently absent or at great depth in NPR-4 except for the complex structural belt along the front of the Range and in the extreme eastern part of the depositional trough outside of NPR-4.

With this brief geologic sketch we might next follow the oil exploration history of this area. In 1923 the U. S. Navy decided that the first step necessary to a proper administration of this Reserve was adequate geographic and geologic

knowledge. The Geological Survey was asked to examine and report on the area. This was done in the years 1923 to 1926 and the results were published as Geological Survey Bulletin 815. One of the significant conclusions at that time in regard to oil accumulation was that "structural features favorable for retaining petroleum were widespread" in Cretaceous rocks but source beds of oil were less apparent. An oil shale then thought to be of early Cretaceous age was described as a probably widespread formation that may "have supplied extensive pools in widely distributed favorable structural features in overlying rocks, many of which should be found at depths within reach of the drill". This was the evaluation of Smith and Mertie in 1930.

In 1944 the U. S. Navy again began an exploration program in an attempt to further evaluate the petroleum possibilities of NPR-4; the objective is most commonly stated as an adequate evaluation of the petroleum possibilities of NPR-4 and the adjoining area. In 1945 the Geological Survey was asked to participate in the geologic aspects of this program. Since that time the Survey has carried on an extensive geologic field program in northern Alaska; has maintained a core analysis laboratory in Fairbanks, Alaska, that is devoted exclusively to this program; has provided specialists, such as paleontologists and petrographers, to work on special problems; has compiled base maps that are used in nearly all phases of the exploration program, and in general has made available the services of the Geological Survey. New techniques have been developed and used to speed up the work, for example, the airborne magnetometer, the use of trimetrogon photographs in map compilation, and the interpretation of geologic features from aerial photographs. Photogeologic maps at a scale of 1:48,000 have been completed for all of the outcrop area and recompiled at a scale of 1:250,000 for much of that area.

Concurrent with the geologic investigations, the U. S. Navy contracted for geophysical investigations (primarily by reflection but also including some refraction studies) in extensive areas where there are few or no exposures of bedrock. This work was done primarily by the United Geophysical Company. In addition, the entire area has been flown with the airborne magnetometer; a cooperative project of the Geological Survey and the U. S. Navy. The United Geophysical Company also completed a gravity survey of all but the southeastern mountainous section of NPR-4. This project utilized small bush planes and helicopters and might also be called an airborne operation.

In most oil exploration programs in remote areas, it is undoubtedly best to complete geological and geophysical studies before drilling is started. It appeared advisable, however, because of wartime urgency to begin exploratory drilling in NPR-4 at the start of the program in 1945.

At that time the only geologic information available to aid in locating a test was the broad reconnaissance studies of 1923 to 26, some additional information on the location of oil seepages, and a preliminary structural study of the

Umiat anticline conducted by a U. S. Navy party in 1944. Oil seepages were known to be present at Umiat, Simpson, Fish Creek, and Humphrey Point and were reported to be present on the lower Meade River, Kuparuk River, and to the east near Demarcation Point. The first test wells drilled were in the Umiat and Simpson area. Umiat Test Well No. 1 was later found to be off structure and was a dry hole. Umiat 2 should have been successful but was a dry hole; apparently conventional rotary drilling had mudded off the oil sands. The Umiat field was not discovered until five years later. The discovery well and other tests at Umiat were based on more complete structural information and were drilled largely with cable tools and oil-base muds. The last test at Umiat was just completed this past year, and the producing area has now been fairly well delimited. Reserve estimates of producible oil made by several individuals and organizations have a very wide range from 30 to over 100 million barrels. This is due primarily to disagreement as to how much can be produced through a permafrost zone in subgraywacke-type sands. Estimates in the range of 50 to 60 million barrels have received the most votes although there is good factual data to indicate that these estimates are low.

At the same time that test wells were started on the Umiat structure, several core tests were also being drilled in the Simpson Seeps area. The oil occurrence in this area proved to be more complicated than originally thought. Thirty-one core tests (ranging in depth from 150 to 1,500 feet) were eventually drilled. Two flowing wells were discovered but the oil reserves are small, perhaps 2½ million barrels. The oil is accumulated in a stratigraphic trap.

Meanwhile, a very large structure, Oumalik, was mapped by the geophysical crews in about the center of the depositional trough. Two core tests were drilled on the structure in 1947 and a deep test was begun in 1949. This test was completed in 1950 at a depth of 11,872 feet. The test began and ended in Cretaceous rocks and no significant oil showings were found.

In 1948 geophysical studies had established the presence of a major basement high in the Barrow area. Drilling near the top of this high discovered gas which is still being utilized at the Point Barrow camp.

In 1949 a test was drilled at the Fish Creek Seep and oil was discovered at relatively shallow depth. The oil is of a very poor grade. Reserves are estimated at about 3½ million barrels.

Several wells were then drilled on local structures around and stepping down from the Barrow "high". No further discoveries were made. One of the most interesting tests was Topagoruk 1 drilled in 1951 to a depth of 10,503 feet. This test penetrated Cretaceous, Jurassic, Triassic, probable Carboniferous rocks and bottomed in Middle or Lower Devonian rocks. Although no further discoveries were made around the Barrow "high", the tests did indicate that no new reservoir beds were coming in from the south within practical drilling depth--12,000 feet or thereabouts. This then completed the evaluation of the Barrow high and nearly all of the Coastal Plain Province.

While some of this was going on, the geological field work began to give indications of favorable sand trends in the Foothills Province and several closed anticlines in addition to the Umiat anticline were mapped. It was concluded that, ideally, if a favorable shore-line type sand trend crossed a closed structure, good results could be expected. Ten shallow-to-moderate-depth tests on six structures were drilled to test this idea. One gas field and 3 gas prospects were discovered but no oil discoveries were made except the Umiat field. Good showings, however, including bleeding cores, were noted. The results show that other gas fields are probably present in the Northern Foothills section and quite possibly several oil fields of the size of the Umiat field.

By 1950 geophysical studies had covered much of the coastal plain area including the extreme western parts of NPR-4. Two closed structures, Meade and Kaolak, were mapped in this area. Geologically these structures were known to be in areas of largely nonmarine Cretaceous beds and older prospective reservoirs were believed to be beyond practical drilling limit. The structures were tested, however, in 1950 and 1951, primarily as stratigraphic tests to get further data for an evaluation of the western part of the Reserve. Meade had good gas prospects but Kaolak was a dry hole. These tests started and bottomed in Cretaceous rocks.

In the last two years and even earlier much interest and considerable field work has been devoted to areas in which pre-Cretaceous prospective reservoirs might be drilled at reasonable depths. The Barrow area was tested for such reservoirs but none were found or indicated. Drilling in the Northern Foothills section around Umiat and Oumalik, plus geophysical studies in these areas, strongly indicated that pre-Cretaceous beds and more certainly Paleozoic beds were beyond practical drilling depth. It seemed, therefore, that a location would have to be found in the Southern Foothills section, in the belt of complexly folded and faulted sediments. Another possibility, one which the geologists have supported for several years was to go east to where the depositional trough rises and laps up onto the north bend of the Brooks Range. Geophysical work in the Southern Foothills section had been unsuccessful at first but good results were obtained later.

This, then, is a very sketchy summary of the exploration history. A total of 34 test wells and 41 core tests with a total footage of about 170,000 were drilled on 18 structures over a period of eight years. Information gained by the extensive geological and geophysical studies will immeasurably aid future exploration in northern Alaska. Northern Alaska, one of the most promising petroleum provinces in Alaska, is no longer unknown but is now the best-known large area in Alaska.

A method of evaluation could be a comparison of the ratios of wildcats to discoveries in northern Alaska with such ratios as published by this Association for the years 1944-1946 in other unproven areas. In the years 1944-1946 in unproved areas, the ratios were 1 to 9 for even a very small field such as Simpson or Fish Creek; 1 in 53 for a field comparable to Umiat, and 1 in 991 for a very large field. In northern Alaska, 35 test wells which were not all wildcats and 41 core tests (which were for stratigraphic information) were drilled. Three oil discoveries, one gas, and 3 prospective gas discoveries were made. This is far better than the average.