

## **The history of hydrocarbon exploration on the Alaskan North Slope: a century of public and privately funded earth science for the common good**

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The long history of petroleum exploration in northern Alaska is a classic illustration of the benefit of interaction between publicly funded scientific research organizations and the private sector for the overall public good. The successful oil industry exploration program that resulted in the discovery of the supergiant Prudhoe Bay field built on a geologic framework established by the US Geological Survey (USGS). Prudhoe Bay—by far the largest oil field in North America--and subsequent major discoveries constitute one of the most important petroleum provinces in North America—a province that has made a huge contribution to the national economy. Ongoing collaboration between the USGS, the Alaska Division of Geological and Geophysical Surveys (DGGs), and Division of Oil and Gas (DOG) continues to provide basic regional geological data and interpretations for the use of both private and public sector earth scientists in evaluation of and exploration for energy resources for the state and the nation.

Geological exploration of northern Alaska began in 1901 with a pioneering reconnaissance by F.C. Schrader and W.J. Peters of the USGS. Their field party crossed the Brooks Range through Anaktuvuk Pass, floated down the Anaktuvuk and Colville Rivers in canoes to the Arctic Ocean, and then followed the coast westward to Barrow and south to Cape Lisburne. In this exploration, Schrader recognized the presence of coal-bearing Cretaceous and Tertiary sediments in the Brooks Range foothills and correctly surmised the presence of a sedimentary basin beneath the North Slope. The first published mention of petroleum on the North Slope was in 1908 by Alfred H. Brooks of the USGS, who reported analyses of oil collected by Ernest deKoven Leffingwell from a major oil seep near Cape Simpson. Brooks commented that "These fragmentary data point to the conclusion that there may be a petroleum field in this extreme northern part of Alaska".

Leffingwell's geological mapping, which focused mostly on the Canning River region of the northeastern Brooks Range in what is now part of the Arctic National Wildlife Refuge (ANWR), was carried out in the course of the most remarkable scientific investigation ever conducted in northern Alaska. During the summers from 1907-1914, his privately funded expedition, which consisted of himself and one or two helpers, established a triangulation net and surveyed the entire coastline from the Canadian border to Point Barrow. His bedrock geologic mapping was done in the winters when dog team travel on the frozen tundra simplified access to the mountain outcrops. In the course of this mapping he named the Sadlerochit, Shublik, and Kingak formations---which are major source and reservoir units in the Prudhoe Bay field. He was also the first to many features in what is now known as permafrost. His work on the Canning River region was published by the USGS in 1919 as Professional Paper 109, which is a scientific classic. Here he again reported the presence of the major oil seeps near Cape Simpson and also seepages near Wainwright. He suggested that there might be an oil field between Wainwright and Smith Bay, and noted that the oil-bearing rocks may also occur in other

parts of the Arctic Slope. His report attracted the attention of the U.S. Navy, which in WW-I had emerged as an international naval power, and had recently converted from coal to diesel power. Concern for long range energy supplies thus led to the establishment of several naval petroleum and oil shale reserves, and in 1923, a large area of the North Slope, including the Simpson oil seeps, was withdrawn as Naval Petroleum Reserve #4 (NPR-4). Elk Hills in California, and the infamous Teapot Dome in Wyoming were two of the other Naval petroleum reserves.

The first systematic exploration of the new petroleum reserve occurred during the summers of 1923 to 1926, when the USGS dispatched several reconnaissance field parties that traversed a number of the rivers on the central and western North Slope. Some of these explorations, in an era before the availability of any detailed maps, air support, or motorized tundra transportation, were sagas of discovery, adventure, and survival in a remote unmapped land. Several of the field parties began in the winter by dog team to the headwaters of the rivers to wait for breakup so that canoes could be used for transportation down the rivers. Some of the place names that resulted--- Disappointment Creek, Noluck Lake, and Desperation Lake--provide mute testimony to the rigors of some of these early scientific investigations. This exploration was carried out by some well-known pioneers of geology, including Jim Gillluly, John B. Mertie, P.S. Smith, and W.T Foran. The results, which began to truly outline the geological framework of northwestern Alaska, were combined and published in 1930 as USGS Bulletin 814 by P.S. Smith and John B. Mertie.

NPR-4 and the North Slope in general were then essentially forgotten until WW-II, when possible need for long-range fuel supplies again renewed the attention of the Navy on northern Alaska. By the time a major exploration program could be organized, the war had ended, but nevertheless from 1945 to 1953, the Navy with the technical assistance of the USGS carried out an extensive exploration program in NPR-4. This program included a number of major surface geological parties, seismic, gravity, and magnetic geophysical programs, and the drilling of a number of core holes and 36 relatively shallow test wells, most of which tested mid- Cretaceous sands of the Nanushuk Formation in the foothills belt. A number of oil and gas shows and several small noncommercial oil and gas accumulations were found, including a small oil field at Umiat in the Nanushuk, and the South Barrow gas field in thin Jurassic sandstones adjacent to a meteor impact feature.

An important contribution of this program was delineation of the stratigraphic and structural framework of the North Slope and northern flank of the Brooks Range and compilation of a much more detailed regional geologic map of the area. This framework was developed by a close-knit group of USGS geologists, some of whom continued their studies on the North Slope until very recently. All of the technical information from the projects of the 1940's and 1950's was published in an extensive series of USGS Professional Papers, technical reports, and journal articles that were of incalculable value to the next wave of explorers who came with the oil industry in the early 1960's.

For many companies, work on the North Slope in the 1960's began with helicopter-supported reconnaissance surface geological field parties operating from tent

camps on lakes scattered through the foothills and northern flank of the Brooks Range. These field parties began with the regional framework established by the USGS and expanded into more detailed mapping and topical stratigraphic studies. This was followed by wintertime reconnaissance seismic exploration and initial acquisition of federal leases in the northern foothills of the Brooks Range. State of Alaska selection of lands on the Arctic coastal plain in early 1964 was followed by two state lease sales in 1964 and 1965 and third sale in 1967. Large lease tracts overlying significant structures identified by seismic surveys on the coastal plain were acquired by a number of major companies in the area of the Colville River delta and adjacent to an obscure place called Prudhoe Bay, which had been named by British explorer Sir John Franklin in 1825.

In the early 1960's several exploratory wells were drilled by British Petroleum and Sinclair Oil on Federal leases on foothills anticlines, followed by a deeper well in 1966 on the major structural high identified on State lands by seismic data near the Colville River delta. Subsequently, Richfield Oil--later merged with Atlantic Refining Company to become ARCO--and its partner Humble Oil (later renamed Exxon) drilled a foothills structure near the present Dalton Highway, and then moved north to drill a significant seismic prospect on their large state lease block at Prudhoe Bay. In the spring of 1968, this well--Prudhoe Bay State #1--encountered a thick and prolific reservoir containing both oil and gas in the Triassic Sadlerochit Formation. A second well--Sag River State #1--seven miles away and 400 feet stratigraphically lower than the discovery well--confirmed the discovery of the supergiant Prudhoe Bay field. Reserves were initially estimated at 9.6 billion barrels---the largest field in North America and over twice the size of the giant East Texas field. This event kicked off the wave of exploration and discovery on the North Slope and adjacent offshore that continues today. Prudhoe Bay has now produced over 13 billion barrels of oil, and its 26 trillion cubic feet of natural gas await a pipeline to markets in the South 48.

In the mid-1970's, the rapid pace of exploration on state lands on the North Slope, combined with the 1973 Arab oil embargo and increasing national reliance on imported oil, resulted again in renewed interest by the Navy in exploration of its petroleum reserve. In 1975, a third phase of exploration in NPR-4 began with an active seismic exploration and five well drilling program carried out by the Navy and its contractors Husky Oil and Tetratex, Inc. In 1977, Congress transferred the petroleum reserve to the Department of Interior, designated it the National Petroleum Reserve in Alaska (NPR), and mandated an additional 21 well exploration program. With this, the USGS took over administration of the program, with Husky Oil as prime contractor. From 1977 to 1981, an extensive reconnaissance seismic grid was shot throughout NPR, and a number of wells were drilled to test a variety of prospects and to provide stratigraphic control in remote areas. A systematic logging and sampling program was carried out to provide subsurface data and material for detailed paleontologic and geochemical analyses. Other than the Walakpa gas field just south of Barrow, no significant discoveries were made, but the program resulted in a large database of subsurface information and geophysical data, all of which is in the public domain.

A 1980 resource assessment of the hydrocarbon potential of NPR was carried out by the USGS as part of studies to assess the value of Alaska lands before the passage

of the Alaska National Interest Lands Conservation Act (ANILCA). The study estimated a 95% chance of 300 million barrels and a 5% chance of 5.4 billion barrels of recoverable oil in NPRA, with a mean of 2.1 billion barrels--a figure that was roughly comparable to the estimate for the Arctic National Wildlife Refuge (ANWR) to the east, developed in a similar modeling and appraisal program. But exploration of ANWR, originally withdrawn from entry in 1960, remains in limbo.

From 1982 to 1984, the Federal government held four competitive lease sales in NPRA, and over 1.4 million acres were leased by the oil industry. However, only one well was drilled near Barrow. The lack of follow-up exploration after these sales was probably due both to the regional exploration slowdown as a result of the 1985 collapse of oil prices and to the level of exploration activity on state leases closer to the trans-Alaska pipeline and Dalton Highway infrastructure in the Prudhoe-Kuparuk area.

In 1983, the Alaska Division of Geological and Geophysical Surveys (DGGS) began a series of field mapping projects on the North Slope in and adjacent to both NPRA and ANWR. This program, in collaboration with ongoing field studies by the USGS and with the participation of faculty and students of the University of Alaska, Fairbanks (UAF), continues to the present day but in recent years has been hampered by limited state funding for petroleum-related projects. Since 1994, most of the DGGS field studies and analytical work on the North Slope have been supported by a consortium that has consisted at various times of ARCO Alaska and Phillips Petroleum (both now part of ConocoPhillips), Anadarko Petroleum, BP Exploration, the Canadian companies PetroCanada and EnCana Oil and Gas, ChevronTexaco, TotalFinaElf, Unocal, Exxon USA, Shell Oil, Arctic Slope Regional Corporation, North Slope Borough, Alaska Division of Oil and Gas, Alfred James--an independent from Kansas, and the USGS.

DGGS projects sponsored by the consortium were initially concentrated on geologic mapping in the northwestern DeLong Mountains in western NPRA and on adjacent State and Native lands. In addition to mapping, the studies carried out studies of facies and depositional environments of Neocomian and mid-Cretaceous shelf and deltaic sandstones and on source rock potential of Triassic, Jurassic, and Neocomian organic-rich shales. A new type of foothills play in the Nanushuk Formation has been documented in which Nanushuk deltaic deposition has been partly controlled by syn-depositional uplift and thrusting of organic-rich Triassic and Jurassic source rocks. Similar syndepositional structural deformation may also have influenced Nanushuk deposition in the east-central Brooks Range foothills.

After the 1996 announcement by ARCO and Anadarko of the discovery of the Alpine oil field, now estimated to contain over 400 million barrels of recoverable oil in Jurassic sandstones just outside northeastern NPRA, exploration interest again returned to NPRA. Following a Federal lease sale in 1999, a number of exploratory wells were drilled in the 2000-2001 drilling season. Five of the wells were reported to have encountered oil and gas, and additional wells were drilled in 2002 to test other prospects and to evaluate the earlier discoveries. Future lease sales are planned in central, western and southern NPRA.

As a result of the renewed industry exploration in eastern NPRA in addition to increasing interest in the gas potential of the Brooks Range foothills belt, recent studies by the USGS, DGGs, and DOG have concentrated mostly on the eastern and east-central North Slope. Since 1996, the USGS has carried out a number of topical field projects and released detailed reassessments of the oil and gas potential of NPRA and ANWR, and is currently carrying out an assessment of the lands between NPRA and ANWR. Ongoing DGGs projects funded by the industry consortium and USGS have focused on facies studies of the Cretaceous Nanushuk and Tuluva formations, on source rock evaluation--particularly in organic-rich Triassic and Jurassic rocks, and 1:63,360 mapping of quadrangles important for understanding of the structure and stratigraphy in the foothills thrust belt and northern foothills of the Brooks Range.

A joint USGS/DOG project in collaboration with DGGs is focused on compilation and publication in electronic format of a modern revised geologic map of the North Slope foothills outcrop belt and northern flank of the Brooks Range. Currently available maps of the North Slope are at several different scales, mapped by many different geologists over a period of more than 50 years, using a wide variety of structural annotation and stratigraphic names, some of which have long been abandoned. The revised compilation will be at a uniform scale of 1:250,000 in the northern foothills and 1:125,000 scale in the Brooks Range thrust belt, using modern stratigraphic nomenclature and consistent cartographic standards, utilizing all available mapping, including industry contributions. A longer-range objective is the preparation of new generalized geologic map of the entire North Slope and Brooks Range. The long-term collaborative interaction between the public and private sectors in hydrocarbon exploration in northern Alaska is expected to continue for a number of years.