Arctic National Wildlife Refuge (ANWR) Coastal Plain Resources

October 2025

Prepared for

Alaska Industrial Development and Export Authority
813 W Northern Lights Blvd
Anchorage, AK 99503

Prepared by

ASRC Energy Services, LLC
3900 C Street, Suite 701
Anchorage, Alaska 99503

This page intentionally left blank.

Table of Contents

Distribution

LIST OF TABLES AND FIGURES

TABLES

FIGURES

This page intentionally left blank.

Acronyms and Abbreviations

1002 Area	Alaska National Wildlife Refuge, Section 1002
2-D	two-dimensional
AIDEA	Alaska Industrial Development and Export Authority
ANILCA	Alaska National Interest Lands Conservation Act
ANSCA	Alaska Natives Claims Settlement Act
ANWR	Arctic National Wildlife Refuge
AOG	Armstrong Oil and Gas
API	American Petroleum Institute
ASRC	Arctic Slope Regional Corporation
bbl	barrel
BBO	billion barrels of oil
BLM	Bureau of Land Management
BOPD	barrels of oil per day
BSPD	barrels of sand per day
BWPD	barrels of water per day
DOI	U.S. Department of the Interior
DST	drill stem test
GOR	gas-oil-ratio
GSI	Geophysical Service, Inc.
KIC	Kaktovik Inupiat Corporation
LCU	Lower Cretaceous Unconformity
MCA	Marsh Creek Anticline
MCF/D	thousand cubic feet per day
MD	measured depth
mD	millidarcy, a measure of permeability
MMBO	million barrels of oil
MMCFD	millions of cubic feet (of gas) per day
NAMSS	National Archive of Marine Seismic Surveys
NPR-A	National Petroleum Reserve – Alaska
OGIP	original-gas-in-place
OOIP	original-oil-in-place
Scf/bbl	standard cubic foot per barrel
TAPS	Trans-Alaska Pipeline System
TCFG	trillion cubic feet of gas

TOC	total organic carbon
TVD	true vertical depth
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1.0 EXECUTIVE SUMMARY

The Arctic National Wildlife Refuge (ANWR) Coastal Plain is the most prospective unexplored onshore area in North America with reserves estimates ranging from 5.7 to nearly 16 billion barrels of technically recoverable oil. ANWR was first developed in 1960 by Dwight D. Eisenhower as a federally protected area following a significant rise in environmental awareness and activism in the United States. The discovery of Prudhoe Bay in 1968 and subsequent construction of the Trans-Alaska Pipeline System (TAPS) in the 1970s brought economic opportunities to the state and nation. Following the discovery of Prudhoe Bay and the realization of Alaska's potential for economic development, the Alaska Natives Claims Settlement Act (ANSCA) was passed in 1971 to settle the long-standing aboriginal land claims by Alaska's indigenous people to create a "fair and just" resolution to their claims. In the spirit of self-determination, ANCSA allows the Alaska Native people to independently manage and develop their lands for cultural and economic benefit.

The discovery of oil and gas on the North Slope, coupled with growing concerns over environmental protection and Alaska Native land rights, set the stage for the Alaska National Interest Lands Conservation Act (ANILCA). Signed into law by President Jimmy Carter in 1980, ANILCA served as a "grand compromise," balancing national interests in natural resource development with the need for environmental conservation. The passage of ANILCA created the Section 1002 Area (1002 Area), also known as the Arctic Refuge Coastal Plain, within ANWR for further study of its oil and gas potential. This led to several studies over many years conducted by the U.S. Department of Interior, including biological studies, surficial geological studies, and the acquisition and interpretation of two-dimensional (2-D) seismic data. Geologists conducting the studies concluded that the Arctic Refuge Coastal Plain remains the most promising onshore oil and gas exploration area in the United States.

Despite Congress passing ANILCA, the region was not open for oil and gas leasing and remained closed to development until the Tax Cuts and Jobs Act (Tax Act) was passed in 2017 by Congress opening the Coastal Plain to oil and gas leasing. The Tax Act aimed to reduce taxes for citizens and business owners while offsetting federal revenue lost from taxpayers and replacing it with revenue from resource development.

In the 37 years between the passage of ANILCA and the 2017 Tax Act, several discoveries have been made on the North Slope, including along the western edge of the 1002 Area. Four tectonostratigraphic sequences have been identified on the North Slope: the Franklinian, Ellesmerian, Beaufortian, and Brookian sequences, listed from oldest to youngest, each associated with several play types. The 1002 Area is divided into two regions: "undeformed" and "deformed," which are described based on the degree of deformation resulting from mountain-building processes. The deformed area has undergone extensive folding and thrusting due to the uplift of the nearby Brooks Range, while the undeformed area has experienced minimal disturbance, with Brookian sediments infilling a deep basin. These regions are separated by the southwest-northeast-trending Marsh Creek Anticline (MCA).

Previous studies assigned the highest oil and gas potential in structural plays in the older Franklinian and Ellesmerian sequences to the east of the MCA. Over time, younger stratigraphic plays of the Beaufortian and Brookian sequences, to the west of the MCA, have become more important. In particular, the discovery and development of the Pikka and Willow Topset play, of the Nanushuk in the central North Slope, during the past decade has made this the hottest exploration play type on the North Slope. Apache Corporation (a subsidiary of APA Corporation) and its partners Lagniappe Alaska LLC (affiliated with Armstrong Oil and Gas) and Oil Search Alaska LLC (a subsidiary of Santos Ltd.) have confirmed a discovery in a Paleocene-aged Topset play approximately 15 miles west of the 1002 Area, and the regional geology indicates that the Topset play extends into the 1002 Area. The long-standing paleo-Canning River depocenter enhances the prospectivity of the Paleocene and Eocene Topset play in the western part of the 1002 Area. The U.S. Geological Survey (USGS) estimated in 1998 that the Topset play in the 1002 Area has a mean value of 15.45 billion barrels of oil (BBO) of original oil-in-place (OOIP) and 6.18 BBO in technically recoverable reserves. ASRC Energy Services (AES) estimates that the western part of the 1002 Area, the focus of this study, contains 3 to 5 BBO in technically recoverable oil. This estimate is comparable to the Nanushuk Formation for both the Pikka and Willow topset trends combined, which are independently estimated to have approximately 1 BBO in recoverable reserves.

The paleo-Canning River depocenter also enhances the prospectivity of the Paleocene and Eocene Turbidite play in the western part of the 1002 Area. The Sourdough, Flaxman Island, and Stinson #1 turbidite discoveries lie just west and north of the 1002 Area and within the paleo-Canning depocenter. Turbidite prospects in the 1002 Area are on trend with these turbidite discoveries. The USGS (1998) has estimated that the Turbidite play in the 1002 Area has approximately 5.33 BBO of OOIP and 1.6 BBO in recoverable reserves. It is estimated that the focus area contains an estimated 1.0 BBO in recoverable reserves.

There is a high probability that the Thomson Sandstone, the primary reservoir of the Point Thomson Field, extends eastward across the boundary of the 1002 Area. While the Thomson Sandstone, which is the localized equivalent to the Kemik Sandstone, may be present in the 1002 Area, its extent remains uncertain. It may also be deep and gas prone.

The Turbidite, Topset, and Thomson/Kemik play have the highest potential in prospectivity for oil and gas in the 1002 Area due to its location within the undeformed area, its proximity to established infrastructure to the west on state land, and discoveries made as close as a half a mile to the 1002 Area's western boundary. These conclusions are based on previous geological assessments, well control to the west, and recent successful play type discoveries. This report aims to provide a background to the history of the 1002 Area, summarize geological studies, and summarize analog fields in recent discoveries. Due diligence should be conducted, and the findings should be carefully considered.

2.0 INTRODUCTION

The Arctic National Wildlife Refuge (ANWR) is located along the northeast corner of Alaska (Figure 2-1). It was originally established in 1960 by President Dwight D. Eisenhower as a federally protected area comprising 8.9 million acres. In 1980, Congress passed the ANILCA which was subsequently signed into law on December 2nd by President Jimmy Carter is widely regarded as the single largest act of conservation in U.S. history and created over 100 million acres of newly protected areas in Alaska. The origin of ANILCA can be traced back to ANCSA, of 1971, which resolved indigenous land claims and set the stage for further land conservation efforts.

Figure 2-1 State of Alaska Arctic National Wildlife Refuge

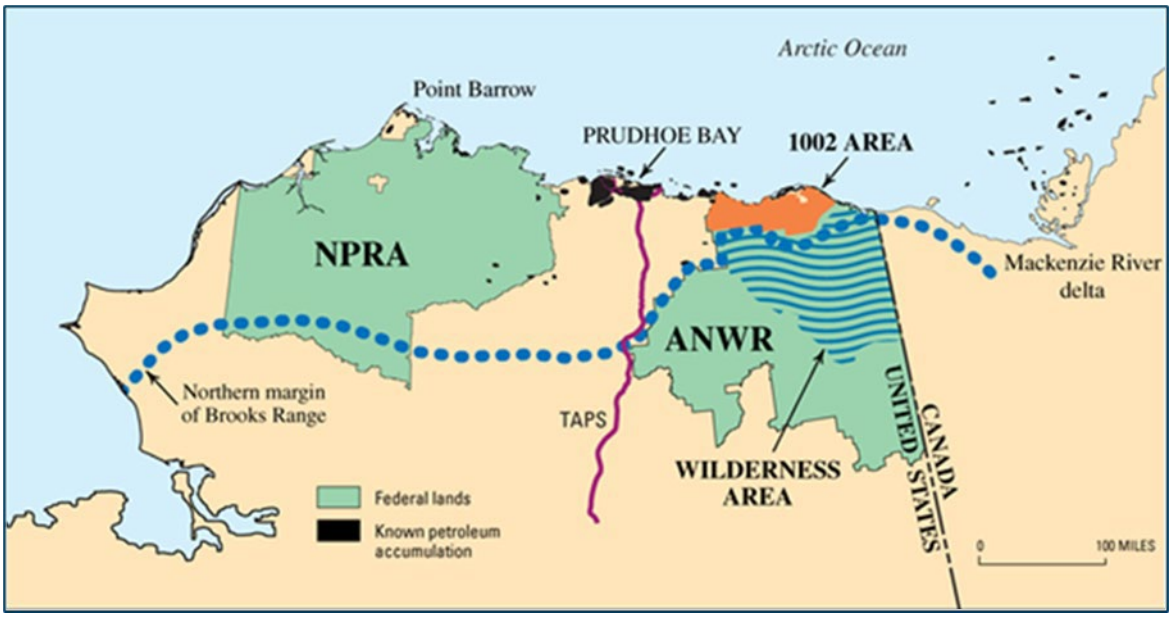
Source: Schepp (2024)

As part of ANILCA, 1.5 million acres of ANWR, located along the Coastal Plain, was specifically set aside by Congress for further study of its oil and gas potential. This is known as the Section 1002 Area (1002 Area), as well as the Arctic Refuge Coastal Plain as depicted on Figure 2-2.

Following the enactment of ANILCA, the U.S. Department of Interior (DOI) initiated biological and geological research in the 1002 Area to provide a recommendation for future management. In 1987, the DOI published the *Arctic National Wildlife Refuge Coastal Plain Resource Assessment* prepared by the U.S. Fish and Wildlife Service (USFWS) in collaboration with the USGS and the Bureau of Land Management (BLM). The resource assessment is a culmination of 5 years of biological baseline studies and surface geological studies, as well as two seasons of seismic exploration surveys. At the time of the

DOI's report, geologists rated the ANWR Coastal Plain as the most promising onshore oil and gas exploration area in the United States. Today, the ANWR Coastal Plain 1002 Area is managed by the USFWS and BLM.

Figure 2-2 ANWR Boundary and 1002 Area



Source: USGS (1998)

Key: 1002 Area = Section 1002 Area of ANWR Coastal Plain; ANWR = Arctic National Wildlife Refuge; NPR-A = National Petroleum Reserve – Alaska

The enactment of ANILCA also triggered a land exchange in 1983 between the United States and Arctic Slope Regional Corporation (ASRC), one of the original 12 regional corporations established following ANCSA. The exchange transferred both surface and subsurface lands from the U.S. to Native lands, where surface rights are managed by village corporation Kaktovik Inupiat Corporation (KIC) and the subsurface rights are managed by ASRC. While exploratory drilling was not permitted in the Coastal Plain without Congressional approval, drilling is allowed on KIC/ASRC lands. As a result, Chevron drilled the KIC #1 well in 1986, located approximately 14 miles east of the village of Kaktovik. The well results remain confidential and will not be discussed in this report. KIC/ASRC lands remain open for exploratory drilling, and with the passage of the 2017 Tax Act, development drilling leading to production is now permitted.

The next resource assessment following the 1987 DOI report was published 11 years later by the USGS, titled *Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment* (1998) and includes an economic analysis. The assessment estimates a mean value of 10.36 billion barrels of technically recoverable oil within the 1002 Area, Native lands (KIC/ASRC), and submerged state land. In 2005, the USGS published an update called *Undiscovered Oil Resources in the Federal Portion of the 1002 Area of the Arctic National Wildlife Refuge: An Economic Update*. This assessment did not change the volume of oil that can be technically recovered; however, it updated the economics to include development scenarios

using a full-cycle cost function that predicts the volume of oil that can be recovered and transported with a market price in 2003 dollars. The updated assessment estimates a mean value of 7.7 billion barrels of technically recoverable oil and 3.5 trillion cubic feet of gas using the development scenarios. Although there have been smaller subsequent economic updates, none is as extensive as the 1987 and 1998 assessments.

This report summarizes the work done by the USGS and from analysis and interpretation of publicly available wells that were drilled adjacent to the 1002 Area since as early as the 1960s and as recently as current exploration activities occurring to the west on state lands. The report also provides pertinent background information, including:

- The 2017 Tax Cuts and Jobs Act and subsequent lease sales
- The history of exploration in the area
- Seismic data
- Play types in the western 1002 Area and their analogs

This page intentionally left blank.

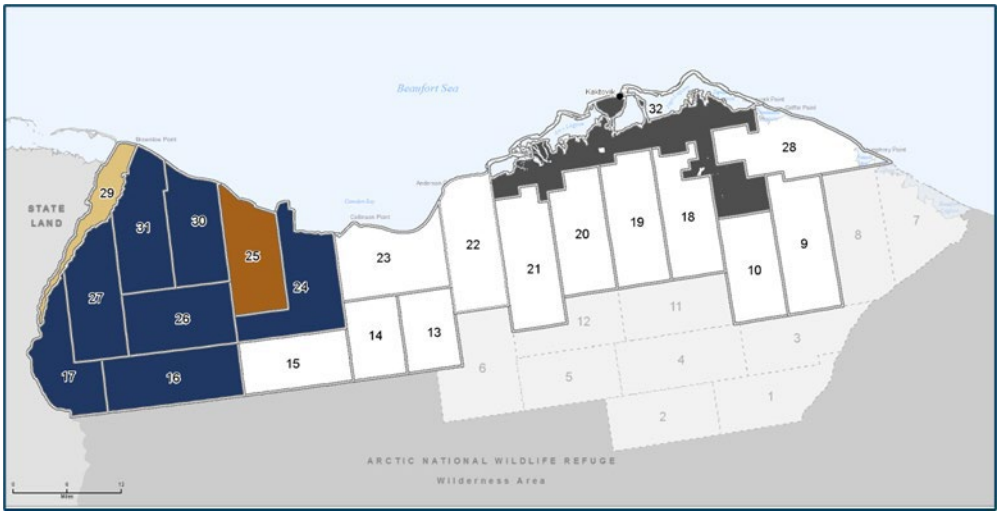
3.0 CONGRESSIONAL ACTS AND LEASE SALES

Since the USGS petroleum assessments of the 1002 Area in 1987 and 1998, no exploration or development activities have occurred in the 1002 Area due to the restrictions in Section 1003 of the ANILCA. Section 1003 states, "Production of oil and gas from the Arctic Wildlife Refuge is prohibited and no leasing or other development leading to production of oil and gas from the range shall be undertaken until authorized by an Act of Congress." This restriction remained in place until 2017, when Congress passed the Tax Cuts and Jobs Act, which directed the BLM to conduct two lease sales in the ANWR Coastal Plain, offering at least 400,000 acres of high-potential hydrocarbons by 2024 (BLM, 2024). As a result, two lease sales were conducted in 2021 and in 2025. Similarly, the One Big Beautiful Bill Act (H.R.1 – 119th Congress) was signed into law on July 4, 2025, directing the BLM to conduct four area-wide lease sales within the Coastal Plain before 10 years of the enactment of no less than 400,000 acres with the highest potential for the discovery of hydrocarbons (Sec. 50104). The lease sales will be conducted every two years starting 1 year after the enactment of the bill.

3.1 2021 Lease Sale

In January 2021, the first-ever ANWR lease sale was held and nine lease tracts (out of a total of 21 offered in the sale) were awarded to three bidders: seven were awarded to Alaska Industrial Development & Export Authority (AIDEA), one to Knik Arm Services, and one to Regenerate Alaska. Both Knik Arm Services and Regenerate Alaska relinquished their leases (AIDEA 2024 and Congressional Research Service 2025). Figure 3-1 is a map of the 1002 Area lease holders at the time of the lease sale.

Figure 3-1 2021 ANWR Section 1002 Area Lease Sale Tracts



Notes: AIDEA lease tracts are highlighted in dark blue, Regenerate Alaska's lease sale tract is highlighted in dark yellow (Tract 29) and Knik Arm Services lease sale tract is highlighted in sepia (Tract 25). Native lands are highlighted in dark grey and are subject to their own independent lease sale because they are privately owned with surface rights held by KIC and subsurface rights held by ASRC. The lease tracts highlighted in white were offered but were not bid on while shaded leases were not included.

Several months later, in June 2021, the DOI announced the suspension of oil and gas leases in the 1002 Area. In Secretarial Order 3401, the Secretary of the Interior stated that her review had identified multiple legal deficiencies in the underlying record supporting the leases, but the order provided limited details on these alleged deficiencies. In response, AIDEA formally requested that the DOI provide both the rationale and the statutory and regulatory evidence supporting the suspension (AIDEA 2024). In September 2023, the Secretary of the Interior cancelled the ANWR leases citing "fundamental legal deficiencies" (Congressional Research Service 2025). As a result, AIDEA filed a lawsuit over the Lease Cancellation Decision in May, 2024 and the judge issued a decision in March, 2025 stating that the DOI lacks the authority to cancel the leases because they did not obtain a court order as described in the Naval Petroleum Reserves Production Act of 1976 (NPRPA). The Tax Cuts and Jobs Act of 2017 directs the Secretary to manage the oil and gas program in the Coastal Plain similar to the NPRPA. Today, AIDEA still holds title to the seven leases originally bid on in the 2021 lease sale.

3.2 2025 Lease Sale

In January, 2025, the second lease sale was held and offered eleven tracts which received zero bids. The lack of bids does not reflect the prospectivity of the Coastal Plain but may reflect more upon the lease sale terms and conditions imposed by the DOI that intentionally limited the use of surface lands which would make the Coastal Plain economically unfeasible (DeMarban 2025). Furthermore, the lease sale was conducted a year after the terms outlined in the 2017 Tax Cuts and Jobs Act creating confusion on whether the lease sale would occur at all since the lease sale deadline had passed. The timing creates uncertainty that a company would have allocated money in their budget to place a bid as they operate within a prescribed budget cycle. The same month, in January, after the lease sale occurred, the President issued Executive Order 14153 that rescinds the earlier lease cancellations and the One Big Beautiful Bill, passed a few months later, requires future lease sales comply with the 2021 Record of Decision that eases restrictions on development.

This page intentionally left blank.

4.0 EXPLORATION HISTORY

4.1 Well Data

The exploration history near and adjacent to the 1002 Area spans from the late 1960s to the present. Table 4-1 summarizes the wells drilled near and adjacent to the 1002 Area; Figure 4-1 provides a map showing well locations; while Figures 4-2 and 4-3 display maps of producing fields and discoveries. The wells in Table 4-1 are organized into three categories based on the years they were drilled: pre-1980, 1980–1990, and post-1990.

Nine wells were drilled before 1980, predating the ANILCA. Sixteen wells were drilled between 1980 and 1990, during the time ANILCA was passed and during the 1987 DOI resource assessment. Finally, fifteen wells were drilled after the 1990s and during the time of the 1998 and 2005 USGS resource assessments. This section provides context to the activities that occurred during major regulatory events.

4.1.1 Pre-1980s

The first three wells on this list were drilled 10 miles southwest of the 1002 Area (outside the map shown on Figure 4-1). The Kavik #1 well, a gas discovery in the Brooks Range foothills, was drilled by Arco Alaska, Inc. in 1969. It targeted the Ellesmerian-aged clastic and carbonate deposits, which were common exploration targets at the time. This discovery prompted additional drilling, including the Kavik Unit #2 well in 1973, located about 2 miles west of Kavik #1 (Figure 4-2). Drilled by the same company, this well also targeted the Ellesmerian-aged clastic and carbonate deposits, specifically the Wahoo Limestone and the Sadlerochit Group. However, it failed to identify any oil and gas accumulation. That same year, Mobil Oil Corporation drilled the Beli Unit #1 well, approximately 5.5 miles north of the Kavik #1 discovery. This well targeted the Ellesmerian-aged Sadlerochit Group and the Shublik Formation but resulted in a dry hole.

During the mid-1970s to late-1970s, Exxon Corporation drilled five wells near the 1002 Area. Canning River Unit B-1, about 5 miles south to the southwestern corner of the 1002 Area boundary, was drilled at the end of 1974 and into 1975. This well targeted several intervals: (1) the Brookian topset, called the Schrader Bluff Formation; and (2) the Ellesmerian-aged Alapah Limestone, Wahoo Limestone, and the Sadlerochit Group. However. this well resulted in a dry hole.

In 1975, Alaska State A-1 was drilled on Flaxman Island, about 3 miles west of the northwestern corner of the 1002 Area. This well targeted two intervals: (1) the Flaxman Sandstone turbidite system within the Canning Formation and (2) the Franklinian-aged basement rock. The well resulted in an oil discovery within the turbidite sandstones.

In 1977, the Point Thomson Unit #1 well was drilled, leading to a major oil, gas, and condensate discovery within the Thomson Sandstone, a Cretaceous (Neocomian) conglomeratic sandstone that is stratigraphically equivalent to the Kemik and Kuparuk sandstones. Appraisal wells Point Thomson Unit #2 and #3 were subsequently drilled in 1978 and 1979, respectively. All three wells were drilled within

the Thomson Sandstone, a Beaufortian-aged reservoir similar to the Kuparuk Sandstone (discussed further in Section 7.3 – Thomson-Kemik Sandstone Play).

The well data in Table 4-1 includes the year the well was drilled, the company that drilled the well, and the intended target. Figures 4-1, 4-2, and 4-3 show well locations and discoveries.

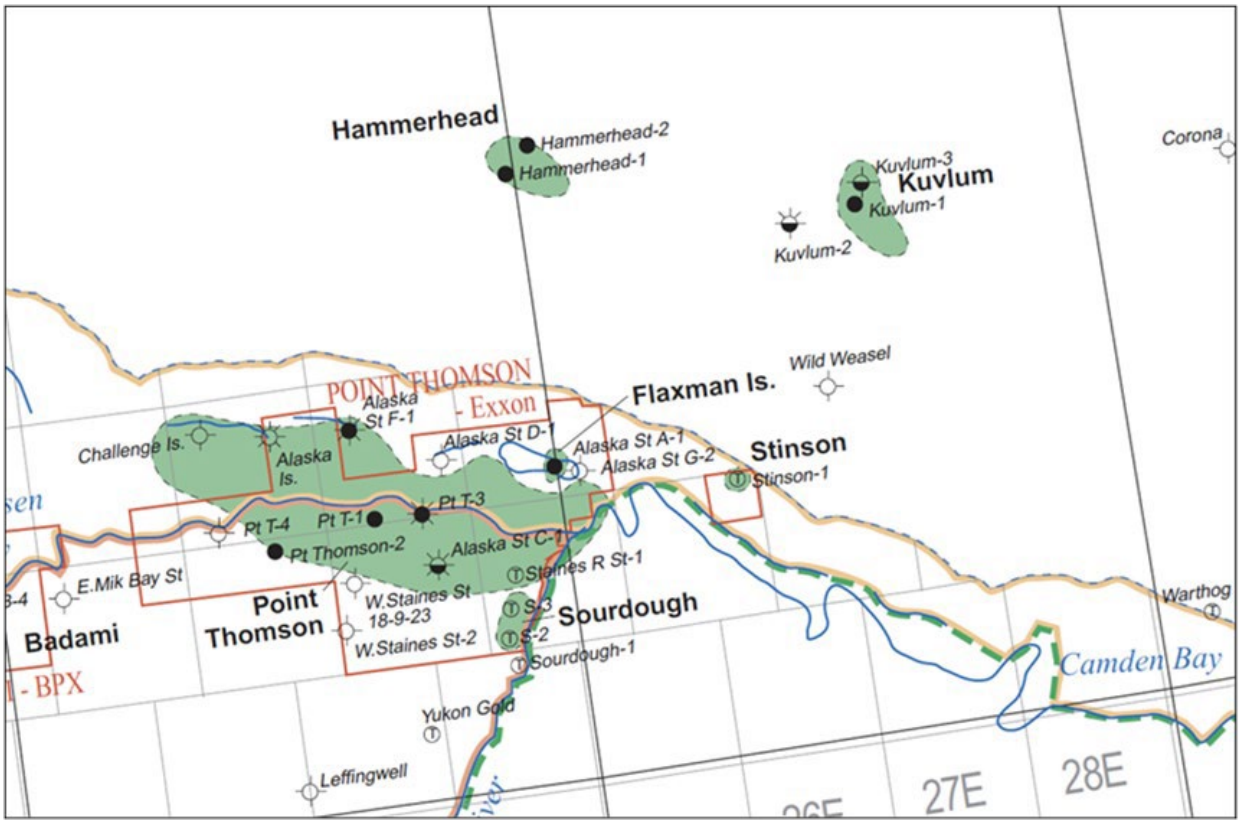
Table 4-1 Exploration Wells Drilled Near ANWR 1002 Area

Category	Well Name	Year Drilled	Operator	Target(s)
Pre-1980s	Kavik 1	1969	Pan American Petroleum Corporation; later Arco Alaska, Inc.	Ellesmerian Clastics & Carbonates
	Beli Unit 1	1973	Mobil Oil Corporation	Ellesmerian Sadlerochit Group and Shublik Fm.
	Kavik Unit 2	1973	Arco Alaska, Inc.	Ellesmerian Wahoo Limestone and Sadlerochit Group
	Canning Riv Unit B-1	1974-1975	Exxon Corporation	Brookian Topset Schrader Bluff Fm.; Ellesmerian Alapah Limestone, Wahoo Limestone, and Sadlerochit Group
	Alaska State A-1	1975	Exxon Corporation	Brookian Turbidite Canning Fm and Flaxman Sandstone; Franklinian Basement Rock
	Pt Thomson Unit 1	1977	Exxon Corporation	Beaufortian Cretaceous Rift Thomson Sandstone
	Pt Thomson Unit 2	1978	Exxon Corporation	Brookian Turbidite Canning Fm; Beaufortian Cretaceous Rift Thomson Sandstone
	Pt Thomson Unit 3	1979	Exxon Corporation	Beaufortian Cretaceous Rift Thomson Sandstone
	Staines River ST 1	1979	ExxonMobil Alaska Production, Inc.	Beaufortian Cretaceous Rift Thomson Sandstone
1980-1990	Pt Thomson Unit 4	1980	Exxon Corporation	Beaufortian Cretaceous Rift Thomson Sandstone
	Challenge Island 1	1980-1981	Sohio Alaska Petroleum Company	Beaufortian Cretaceous Rift Thomson Sandstone
	Alaska State C-1	1980-1981	Exxon Corporation	Paleocene Brookian Turbidite; Beaufortian Cretaceous Rift Thomson Sandstone
	Alaska Island 1	1981-1982	Sohio Alaska Petroleum Company (original operator); BP Exploration (Alaska) Inc. (current operator)	Franklinian Basement Rock
	Alaska State D-1	1981-1982	Exxon Corporation	Brookian Turbidite Canning Fm.; Beaufortian Cretaceous Rift Thomson Sandstone
	Alaska State F-1	1981-1982	Exxon Corporation	Brookian Turbidite Canning Fm.; Beaufortian Cretaceous Rift Thomson Sandstone
	Alaska State G-2	1983	Exxon Corporation	Unknown
	E DE K Leffingwell 1	1984	Union Oil Company of California	Ellesmerian Kekituk Sandstone

Category	Well Name	Year Drilled	Operator	Target(s)
	Alaska State J-1	1984	Exxon Corporation	Brookian Turbidite Canning Fm.; Beaufortian Cretaceous Rift Thomson Sandstone
	KIC Well 1	1985-1986	Chevron USA Inc.	N/A - Well Indefinitely Confidential
	Hammerhead 1 (OCS-Y-849-1)	1985	Union Oil Company of California	Brookian Topset Sagavanirktok Fm.
	Corona 1 (OCS-Y-871-1)	1986	Shell Western E&P, Inc.	Marine Clastics in the Brookian Topset and Turbidites
	Hammerhead 2 (OCS-Y-849-2)	1986	Union Oil Company of California	Brookian Topset Sagavanirktok Fm.
	Aurora 1 (OCS Y-943-1)	1987-1988	Tenneco Oil Company	Brookian Turbidite; Beaufortian Cretaceous Rift; Ellesmerian clastics/carbonates; Franklinian Basement.
	Belcher 1 (OCS Y-917-1)	1988-1989	Amoco Production Company	Paleocene and Cretaceous Brookian Topsets
	Stinson 1	1989-1990	Arco Alaska, Inc.	Brookian Turbidite Canning Fm.; Franklinian Basement Rock
Post-1990s	Badami 1	1990	Conoco Inc.	Ellesmerian Kekituk Sandstone; Brookian Turbidite Badami Sandstones
	Galahad 1 (OCS-Y-1092-1)	1991	Amoco Production Company	Miocene Brookian Topset
	Badami 2	1992	Conoco Inc.	Brookian Turbidite Badami Sandstones
	Kuvlum 1 (OCS-Y-866-1)	1992	Arco Alaska, Inc.	Brookian Topset Sagavanirktok Fm.
	Kuvlum 2 (OCS-Y-865-1)	1993	Arco Alaska, Inc.	Brookian Topset Sagavanirktok Fm.
	Kuvlum 3 (OCS-Y-866-2)	1993	Arco Alaska, Inc.	Brookian Topset
	Wild Weasel 1 (OCS-Y-1597-1)	1993	Arco Alaska, Inc.	Brookian Topset Sagavanirktok Fm.
	Yukon Gold 1	1993-1994	BP Exploration (Alaska) Inc.	Brookian Topset and Turbidite
	Sourdough 2	1994	BP Exploration (Alaska) Inc.	Brookian Turbidite Canning Fm.
	Badami 5	1995	BP Exploration, Inc.	Brookian Turbidite Badami Sandstones
	Badami 4	1995	BP Exploration, Inc.	Brookian Turbidite Badami Sandstones
	Sourdough 3	1996	Hilcorp North Slope, LLC	Brookian Turbidite Canning Fm.
	Warthog 1 (OCS-Y-1663-1)	1997	Arco Alaska, Inc.	Oligocene Brookian Topset; Brookian Turbidite
	Red Dog 1	1999	BP Exploration (Alaska) Inc.	Brookian Turbidite Canning Fm. & Killian Sandstone
	McCovey 1 (OCS-Y-1578-1)	2002-2003	Encana Oil & Gas USA	Brookian Turbidite

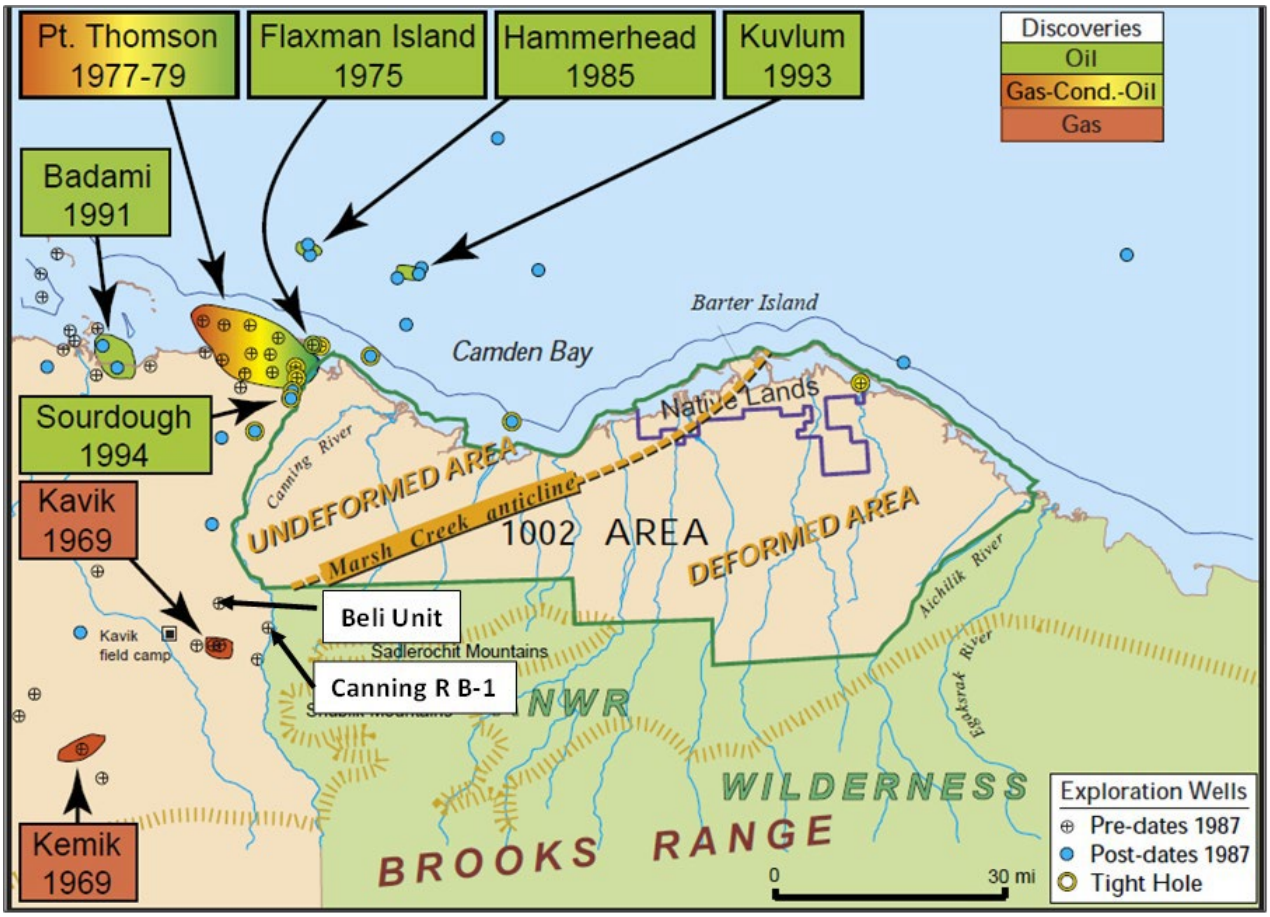
Source: Gregerson & Brown (2021).

Figure 4-1 Well Locations Drilled West and North of the ANWR 1002 Area



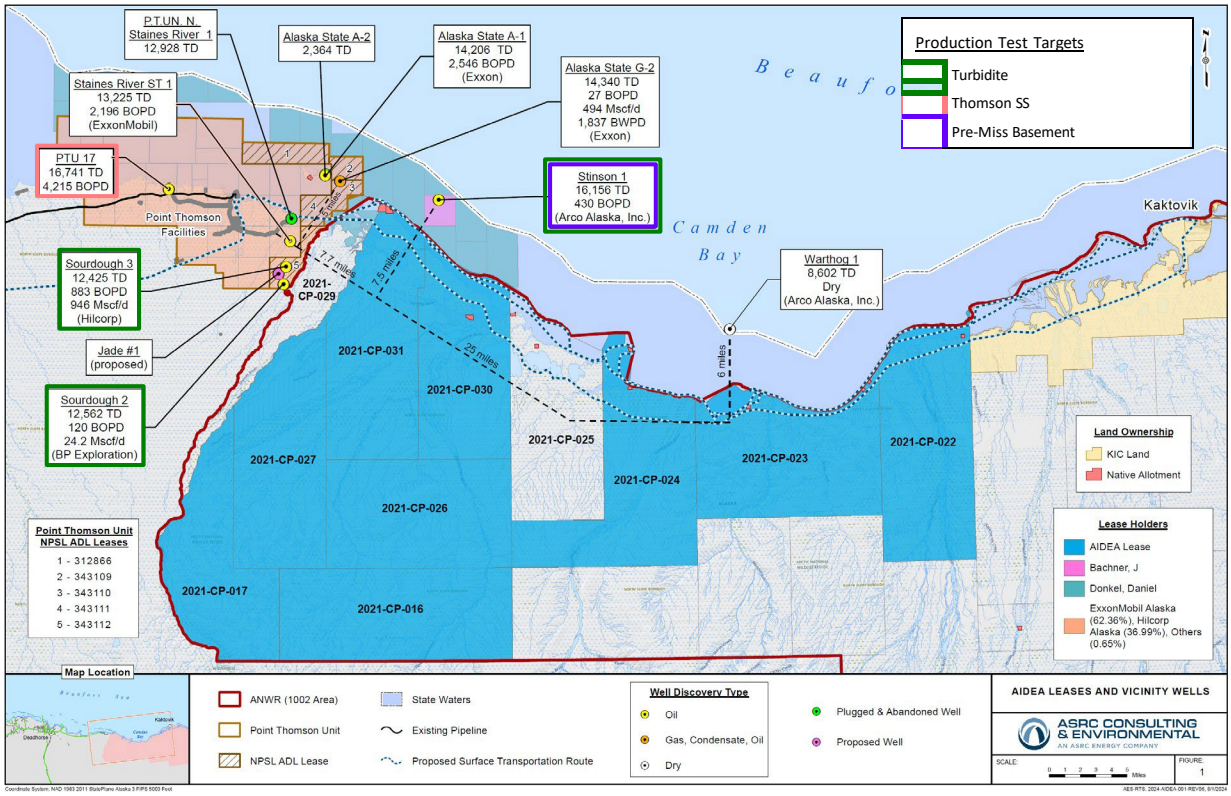
Source: Exploration Geosciences LTD (1999).

Figure 4-2 Fields and Discoveries West and North of the ANWR 1002 Area



Source: USGS (1998)

Figure 4-3 Map of Wells Testing Oil West and North of the ANWR 1002 Area



4.1.2 1980-1990

The beginning of 1980 marked the continued development of the Point Thomson Unit with a fourth appraisal well, Point Thomson Unit #4, by Exxon Corporation. After the establishment of necessary facilities and infrastructure, production at Point Thomson began in 2016, nearly 40 years after the field's discovery. The Point Thomson oil pool remains the only active development project directly adjacent to the 1002 Area, with the Unit boundary touching its westernmost edge (Figure 4-4).

Also in 1980, the Challenge Island #1 well and Alaska State C-1 well were drilled by Sohio Alaska Petroleum Company and Exxon Corporation, respectively. Challenge Island #1 is located approximately 4.5 miles north of Point Thomson Unit #4 on a barrier island, named Maguire Islands, and targeted the Thomson Sandstone. This well did not end in success. Alaska State C-1 was drilled at the end of 1980, soon after ANILCA was passed by Congress. It is located about 4.5 miles to the west of the 1002 Area boundary and about 2 miles to the south of the coastline. It was drilled by Exxon Corporation and targeted a Paleocene-aged Brookian turbidite and the Thomson Sandstone. The well resulted in success, further delineating the Point Thomson field. In 1981, Sohio Alaska Petroleum Company drilled Alaska Island #1, located approximately 3 miles east of the Challenge Island #1 well and about 15 miles west of the 1002 Area. The well targeted the Franklinian Basement but resulted in a dry hole.

In 1981, Exxon Corporation drilled two more wells, Alaska State D-1 and Alaska State F-1, as a continuation of the development of the Point Thomson field. These wells targeted the Thomson Sandstone along with Brookian turbidites from the Canning Formation (likely the Flaxman Sandstone). Alaska State D-1 was located on Flaxman Island about 5 miles west of Alaska State A-1 and nearly 8 miles away from the 1002 Area boundary. Alaska State F-1 was located 4 miles west of Alaska State D-1 on Maguire Island. While Alaska State D-1 was a dry hole, Alaska State F-1 resulted in an oil, gas, and condensate discovery further delineating the Point Thomson field. The KIC #1, drilled by Chevron in 1985 – 1986 on KIC/ASRC lands, is the only well drilled within the ANWR 1002 Area. It was the last well drilled onshore in the area outside of the Point Thomson development. The results of this well remain indefinitely confidential.

The remaining wells drilled during this period were all drilled offshore. The Hammerhead wells, drilled on an anticline by Union Oil, discovered oil within the Oligocene topset delta sandstones (discussed further in Section 7.1 – Topset Play). The Stinson #1 well discovered oil in both Eocene turbidite sandstones (discussed further in Section 7.2 – Turbidite Play) and in the fractured carbonate basement. However, neither of these discoveries has been brought into production due to their size and remoteness. Shell's Corona #1, Tenneco's Aurora #1, and Amoco's Belcher #1 wells were all dry holes.

4.1.3 Post-1990

In 1990, the Badami #1 well was drilled along the coastline to test a Mississippian Kekiktuk target offshore but instead discovered oil in the shallower Badami turbidite sandstones in the Canning Formation, which are of Oligocene age. This led to the delineation of the Badami field with the drilling of Badami #2, 4, and 5. In 1992, Arco drilled the Kuvlum #1 offshore well, targeting a similar formation to the Hammerhead topset discovery. Like Hammerhead, it discovered oil in Oligocene topset sandstones, but the subsequent Kuvlum #2 and 3 delineation wells were dry. BP's Sourdough #2 well, drilled south of the Point Thomson Field and just east of the western boundary of the 1002 Area, discovered oil in a Paleocene turbidite. The delineation well, Sourdough #3, was also successful (discussed further in Section 7.2 – Turbidite Play). Amoco's Galahad #1, Arco's Wild Weasel #1 and Warthog #1, BP's Red Dog, and Encana's McCovey #1 wells, all drilled offshore, were dry. BP's Yukon Gold #1 well, drilled south of the Sourdough discovery into an older turbidite, encountered oil.

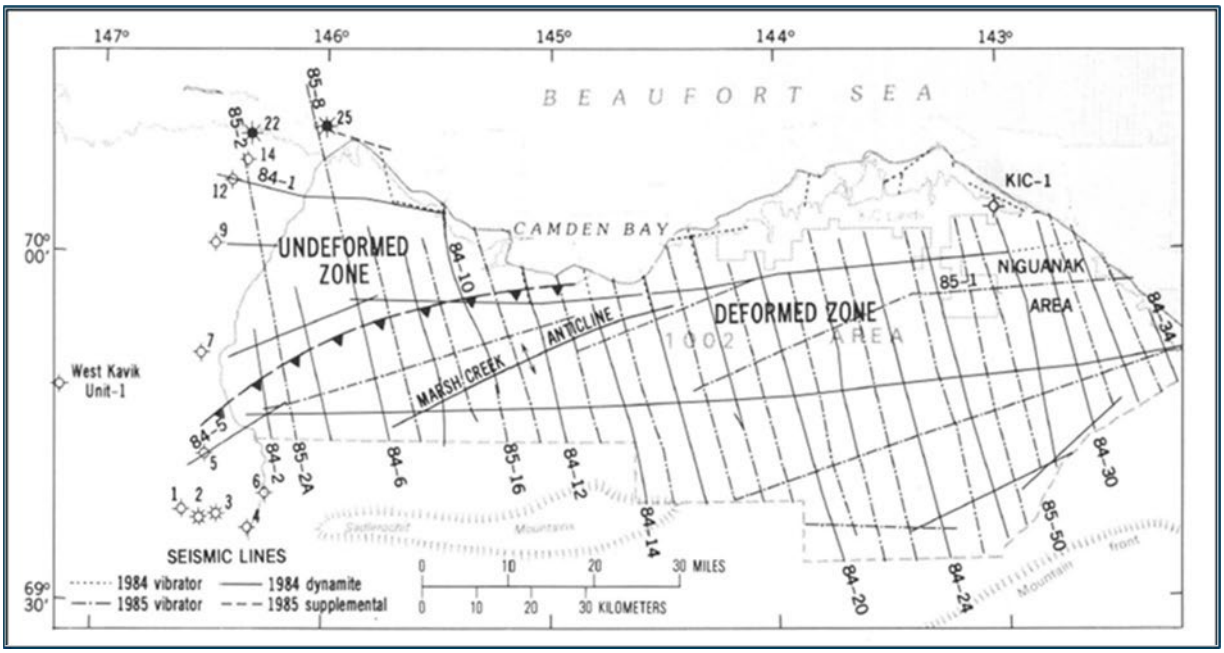
This page intentionally left blank.

5.0 SEISMIC DATA

Following the passage of ANILCA, two seismic exploration seasons were conducted in the 1002 Area by Geophysical Service, Inc. (GSI) on behalf of an industry consortium comprising 25 companies (State of Alaska 2013). In 1984, 606 miles of seismic data were recorded using dynamite, along with 153 miles using Vibroseis. The following year, 692 miles of Vibroseis data were recorded. In total, the three seismic programs collected 1,451 miles of data (Figure 5-1 and Table 5-1). The USGS reprocessed 311 miles of this data, accounting for 21 percent of the entire program (Figure 5-2 and Table 5-2). The acquisition parameters for both the dynamite and Vibroseis programs are detailed in Table 5-3.

Many of the companies who were originally part of the consortium no longer exist. As of 2020, the remaining consortium members consist of 10 companies: Chevron North America Exploration & Production, ConocoPhillips Alaska, Inc., ExxonMobil, Hess Corporation, Hilcorp, Marathon Petroleum Corporation, Murphy Oil Corporation, Occidental Petroleum Corporation (OXY), Shell Energy North America, and Total Energies. Under the ANILCA amendment (16 U.S.C.A. § 3142(e)(2)(C)), these remaining companies or their successors are required to provide the seismic data collected by GSI at a fair cost. Accessing this 2-D seismic data through the consortium is the only way to qualify for participation in a lease sale. Alternatively, these data can be obtained from GSI or the BLM, but doing so would disqualify the interested party from participating in a lease sale under the same amendment provision.

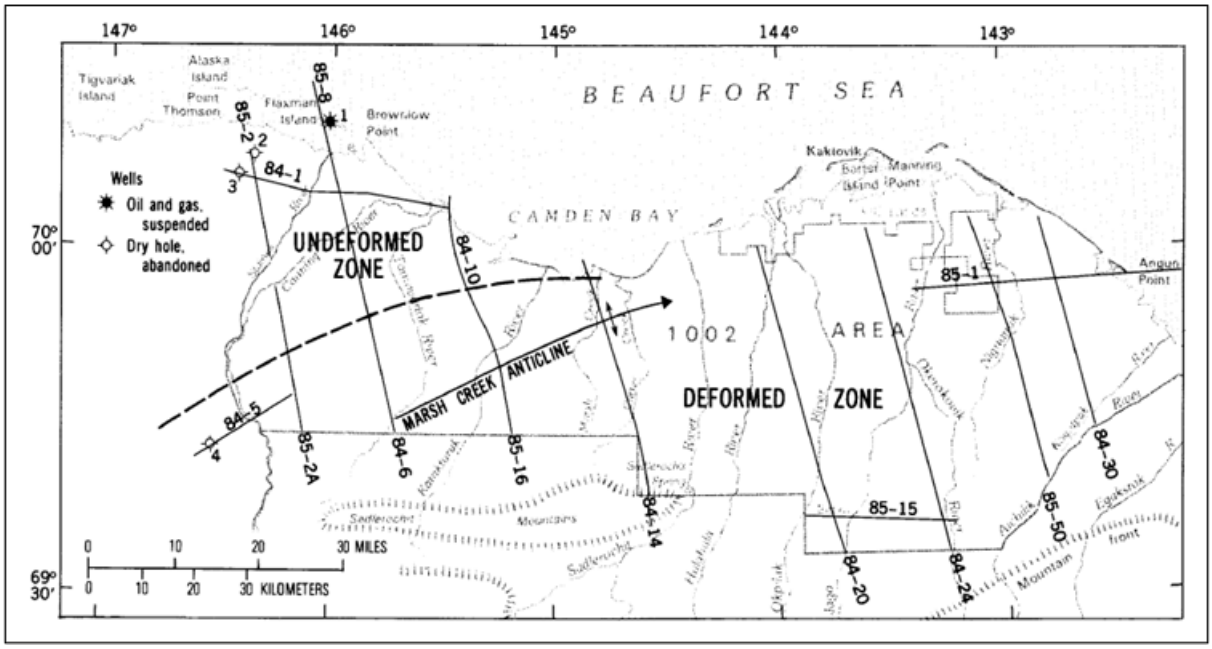
Figure 5-1 Location of the 2-D Seismic Shot Within the 1002 Area



Note: See Table 5-1 for specific program information.

Source: USGS (1987).

Figure 5-2 Location of the 1002 Area 2-D Seismic Lines That Were Reprocessed by the USGS



Note: See Table 5-1 for specific program information.

Source: USGS (1987).

Table 5-1 1984 and 1985 ANWR 1002 Area Seismic Program Acquired by GSI and the USGS

[*, reprocessed by the USGS; **, a registered trademark of Continental Oil Company]

1984		1985
Dynamite	Vibroseis**	Vibroseis**
AN84-1*	ANV84-1	AN85-1*
AN84-2	ANV84-3	AN85-2*
AN84-3	ANV84-7	AN85-2A*
AN84-2	ANV84-3	AN85-3
AN84-3A	ANV84-8	AN85-7
AN84-3B	ANV84-10	AN85-8*
AN84-4	ANV84-12	AN85-10
AN84-5*	ANV84-14	AN85-14
AN84-6*	ANV84-15	AN85-15*
AN84-7	ANV84-16	AN85-16*
AN84-7A	ANV84-17	AN85-17
AN84-8	ANV84-18	AN85-18
AN84-10*	ANV84-19	AN85-19
AN84-11	ANV84-30	AN85-20
AN84-12	ANV84-32	AN85-21
AN84-13	ANV84-34A	AN85-22
AN84-14*	ANV84-34B	AN85-24
AN84-16	ANV84-36	AN85-25
AN84-18	ANV84-38	AN85-26
AN84-20*	ANV84-40	AN85-28
AN84-22	ANV84-48	AN85-30
AN84-24*	ANV84-50	AN85-32
AN84-26	ANV84-52	AN85-34
AN84-28	ANV84-56	AN85-36
AN84-30*	ANV84-58	AN85-38
AN84-32	ANV84-60	AN85-42
AN84-34	-	AN85-44
-	-	AN85-46
-	-	AN85-48
-	-	AN85-50*
-	-	AN85-52
Mileage		
606.64	152.51	692.33
Total mileage		1,451.48
Mileage reprocessed by USGS		311.13
Percent reprocessed by USGS		21.4

Source: USGS (1987).

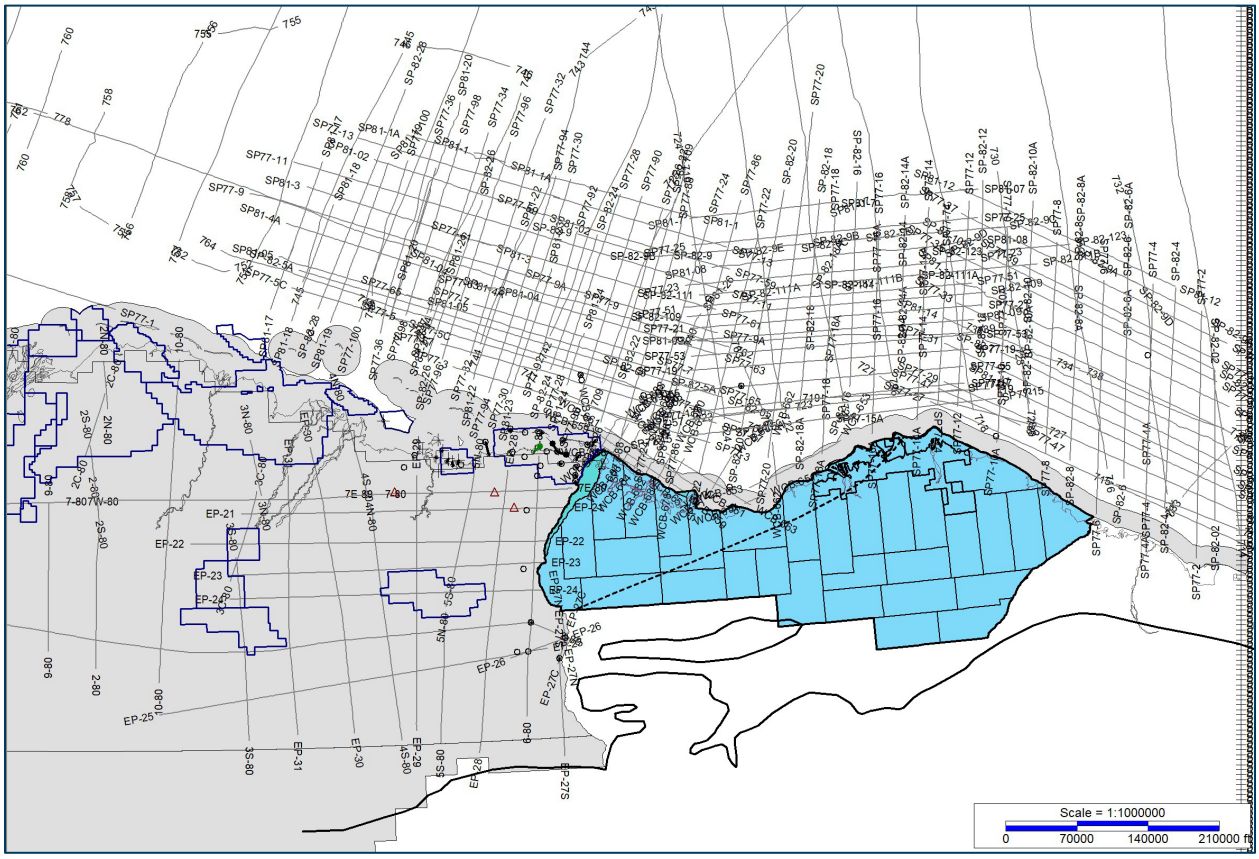
Table 5-2 Dynamite and Vibroseis Acquisition Parameters for the 1984 and 1985 ANWR Seismic Programs Acquired by GSI

Parameter	Dynamite source	Vibroseis source	
	1984	1984	1985
Charge size	60 lb	n.a.	n.a.
Shot depth	75 ft	n.a.	n.a.
Shot interval	220 ft	n.a.	n.a.
	330 ft	n.a.	n.a.
Vibrator interval	n.a.	110 ft	110 ft
Sweep length	n.a.	5 s	8 s
Vibrators/sweep	n.a.	4 or 5	4 or 5
Sweeps/VP	n.a.	8 or 6	12 or 8
Sweep spectrum	n.a.	10–80 Hz	8–90 Hz
Group interval	110 ft, 165 ft	110 ft	110 ft
Groups	120	120	120
Geophone array	linear, 24 geophones per group	n.c.	n.c.
Source array	point	160/164 ft	220 ft
Spread geometry	2805-275-0-275-10725(ft)	2805-275-0-275-1075(ft)	3025-495-0-495-10945(ft)**
	10065-330-0-33010065(ft)*		2915-385-0-385-10835(ft)***
Fold	30	60	60
Recorder	Texas Instruments DFS V	n.c.	n.c.
Sample rate	2 ms	4 ms	4 ms
Record length	8 s	13 s	14 s
Geophones	GSC 20D, 10-Hz resonance	n.c.	n.c.
High cut filter	128-Hz 72-dB/octave cutoff	n.c.	n.c.
Low cut filter	8-Hz 18-dB/octave cutoff	n.c.	n.c.
Miles of data	606.6	152.5	692.3

Source: . USGS (1987)

Additional 2-D data are available outside the 1002 Area for free and can be downloaded from The National Archive of Marine Seismic Surveys (NAMSS). Figure 5-3 shows a map of the available 2-D lines, which consist of various seismic data collected during the 1970s and 1980s. While these data are of poor but usable quality, they would require reprocessing to improve their utility. These data will also be made available for download in the NAMSS data room (NAMSS 2016).

Figure 5-3 Publicly Available 2-D Seismic Data Adjacent to the 1002 Area Both Onshore and Offshore



Source: NAMSS.

AIDEA purchased 1,357 miles of 2-D seismic lines within ANWR. These data need to be reprocessed and interpreted. The interpretations can be compared to the area to the west, where several discoveries have been made (i.e., Topset play, Turbidite play, and Kemik/Thomson Play). Geological geometries such as the shelf margins, topsets, and bottomsets, can also be evaluated, along with new well data drilled since the last USGS assessments. Additionally, the 2-D data can aid in defining a proposed three-dimensional (3-D) seismic survey, which will be critical in identifying and delineating potential reservoirs and for designing a development plan.

This page intentionally left blank.

.

6.0 USGS PETROLEUM ASSESSMENTS OF THE ANWR 1002 AREA

The USGS published three significant petroleum assessments of the ANWR 1002 Area: in 1987, 1998, and 2005. In 1987, the DOI published the *Arctic National Wildlife Refuge, Alaska Coastal Plain Resource Assessment*, following a 5-year long program of biological and geological studies, and recommended to Congress that the entire 1002 Area be considered for leasing. The USGS later published a supplement to this assessment in the form of a Bulletin (USGS 1987), which detailed the geological setting known at the time. Eleven years later, in 1998, the USGS published *The Oil and Gas Resource Potential of the Arctic National Wildlife Refuge 1002 Area, Alaska*, updating the 1987 assessment. An economic update was published by the USGS in 2005. All three assessments are summarized in the following sections.

6.1 1987 USGS Bulletin 1778

The *Petroleum Geology of the Northern Part of the Arctic Wildlife Refuge, Northeastern Alaska, USGS Bulletin 1778*, was published as a supplement to the 1987 DOI Coastal Plain Assessment. This bulletin is broken down into 23 chapters that include information about the regional geological setting, surficial geological processes, stratigraphy, reservoir rocks, source rocks, geochemistry, thermal maturity, seismic reflection data, regional structures, and the assessment of oil in place and recoverable.

The bulletin identifies two structural zones in the 1002 Area: as the “deformed zone” and the “undeformed zone” (see Figures 5-1 and 5-2). The deformed zone encompasses the entire 1002 Area south and east of the Marsh Creek Anticline (MCA), while the undeformed zone includes strata in the northwestern corner of the 1002 Area, above the MCA. The term “deformed zone” comes from the complex nature of structural deformation that has created highly folded and faulted strata. According to the DOI (1987), “Seismic and surface data indicate that all *but* the northwestern quadrant of the 1002 Area is extensively folded and faulted.” Seismic reflections mapped from the pre-Mississippian basement show several large structural enclosures (i.e., anticlines) that may serve as traps. Seismic reflections mapped from the Cretaceous to Paleocene rocks are generally more deformed than the underlying pre-Kingak or overlying post-Paleocene rocks, likely due to their greater mechanical weakness. Seismic data from the Eocene and younger strata show only moderate deformation in the northeastern section. The 2-D seismic also indicates that there is an unconformity between the more structurally complex Cretaceous and Paleocene rocks, suggesting that deformation likely occurred during the late Paleocene to Eocene period and continued episodically into the late Tertiary. The undeformed zone is simply described as an area that has not undergone tectonic deformation. In other words, the sediment in this area (northwest of the MCA) remains relatively horizontal, with minimal displacement or deformation.

Using the 2-D seismic data, 26 structural prospects (Figure 6-1 and Table 6-1) were identified near the top of the pre-Mississippian surface and were considered in the 1002 Area recoverable resource assessment. However, no prospects were sufficiently resolved within the highly deformed Mesozoic and Tertiary rocks using the 2-D dataset from the 1980s. It is believed, however, that the probability of traps occurring in the subsurface in this structural setting is high. The prospects are generalized areas of structures that

include five potential objectives: (1) pre-Mississippian carbonate rocks; (2a) Ellesmerian sequence (clastic rocks); (2b) Ellesmerian sequence (carbonate rocks); (3) Thomson and Kemik sand; (4) turbidites; and (5) lower Neogene topset beds. Of the 26 structural prospects, 25 were identified to include pre-Mississippian carbonate rocks; 16 include Ellesmerian clastic rocks; 14 include Ellesmerian carbonate rocks; 19 include Thomson-Kemik sands; 17 include turbidites; and only 1 includes the lower Neogene topsets. The structural prospects do not include undisturbed turbidite or topset prospects that may occur as stratigraphic traps.

The petroleum geochemistry was also assessed from samples collected from oil seeps and stained outcrops within or adjacent to the 1002 Area. The results indicated that the Hue Shale is the most likely oil source, marking a distinction from the source rocks found in the main Prudhoe Bay field. Maturation studies indicate that all potential source rocks are mature to overmature. Other source rocks identified throughout northeastern Alaska include the Shublik Formation, Kingak Shale, pebble shale unit, and shales in the Canning Formation. The first three units are considered he oil source for the Prudhoe Bay field. However, in the 1002 Area, all units – except the Hue Shale – are gas-prone.

Figure 6-1 Map of Structural Plays in the 1002 Area

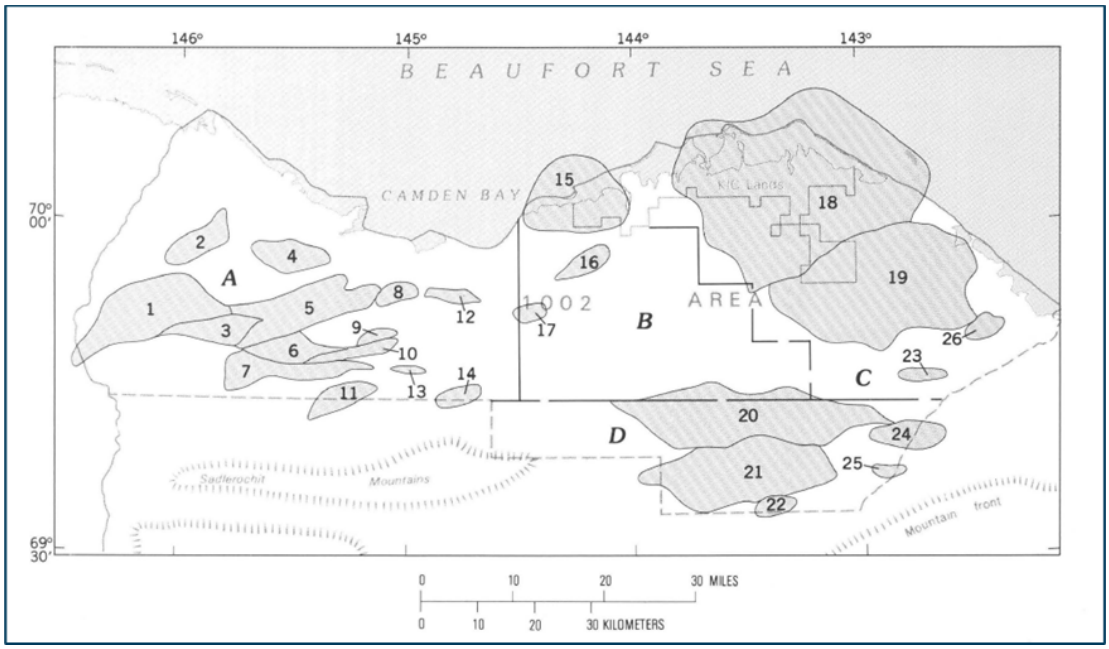


Table 6-1 Data and Potential Objectives on Structurally Mapped Prospects

[Depths are below mean sea level. Potential objectives: 1, pre-Mississipian carbonate rocks; 2a, Ellesmerian sequence (clastic rocks); 2b, Ellesmerian sequence (carbonate rocks); 3, Thomson sand (of local usage) and Kemik Sandstone, undivided; 4, turbidites; 5, lower Neogene(?) topset beds; x, objective with potential; -, no potential]

Prospect	Area (acres)	Size (mi)	Crestal depth (ft)	Lowest closing contour (ft)	Potential objectives						Number of seismic lines
					1	2a	2b	3	4	5	
1	[1]48,512	18 X 6	14,000	15,000	x	x	x	x	x	-	5
2	11,793	8 X 3	14,820	15,000	x	x	-	x	x	-	2
3	13,120	12 X 3	13,000	14,000	x	x	x	x	x	-	3
4	12,922	8 X 3.5	14,900	15,500	x	-	-	x	x	-	4
5	34,234	16 X 4	12,700	15,000	x	x	-	x	x	-	6
6	11,940	10 X 3	11,500	13,800	x	-	-	x	x	-	3
7	18,970	16 X 2	8,500	10,500	x	x	x	x	x	-	6
8	4,880	4 X 2	16,300	17,000	x	-	-	x	x	-	2
9	2,200	4 X 1	12,500	13,200	x	-	-	x	x	-	1
10	6,291	11 X 1	11,900	12,500	x	-	-	x	x	-	3
11	[1]9,430	8 X 3	5,200	6,000	x	x	x	x	-	-	2
12	3,950	6 X 1	19,000	21,000	x	-	-	x	x	-	2
13	1,344	4 X 0.8	10,900	11,500	x	x	x	x	-	-	1
14	[1]4,915	5 X 2	5,640	6,000	x	x	x	x	-	-	1
15	[1]42,500	13 X 10	22,500	23,000	x	-	-	x	x	-	6
16	6,720	6.3 X 2.4	1,230	2,300	-	-	-	-	x	x	3
17	3,170	3 X 2	21,600	22,000	x	-	-	x	x	-	1
18	[1]226,822	27 X 15	13,500	>24,000	x	-	-	x	x	-	16
19	129,587	22 X 13	9,790	17,000	x	x	x	x	x	-	10
20	79,738	30 X 7	11,900	17,500	x	x	x	-	-	-	10
21	[1]65,300	21 X 4	7,500	14,500	x	x	x	-	-	-	7
22	[1]4,560	5 X 2	11,600	12,000	x	x	x	-	-	-	1
23	3,706	5 X 1.5	16,300	16,500	x	x	x	-	-	-	1
24	[1]11,872	8 X 3	10,400	12,000	x	x	x	-	-	-	1
25	[1]2,360	4 X 1	11,950	12,000	x	x	x	-	-	-	1
26	4,954	5 X 3	16,500	17,000	x	x	x	x	x	-	2

[1] Prospect area includes extensions or projections outside the 1002 area as shown in figure 23.2.

Notes: Potential objectives: (1) pre-Mississippian carbonate rocks; (2a) Ellesmerian sequence (clastic rocks); 2b) Ellesmerian sequence (carbonate rocks; (3) Thomson sand and Kemik Sandstone, undivided; (4) turbidites; and (5) lower Neogene topset beds. X marks objectives with potential and – marks no potential. Source: USGS (1987).

6.1.1 Play Types

In the 1987 USGS bulletin assessment of original-oil-in-place (OOIP), seven different play types were identified, spanning Precambrian to Cenozoic rocks. These play types include: (1) Topset play, (2) Turbidite play, (3) Thomson-Kemik play, (4) undeformed Pre-Mississippian play, (5) imbricate fold belt play, (6) folded Ellesmerian/Pre-Mississippian play, and (7) undeformed Ellesmerian play.

These types of plays and the findings from the USGS bullet (1987) are described below;

1. **Topset Play**. This play consists of stratigraphic traps in sandstone reservoirs of Tertiary age and includes rocks representing the topset position of the topset-foreset-bottomset sequence. This play is limited to the northwestern section of the 1002 Area and is generally unaffected by the folding and faulting within the Brooks Range. The play consists of marine and nonmarine deltaic sandstone, siltstone, shale, conglomerate, and minor amounts of coal, with a maximum thickness

of 10,000 feet. The proposed traps in this play are mostly stratigraphic or a combination of structural and stratigraphic, formed against small displacement normal faults. The seal integrity was thought to be fair to poor at the time, possibly allowing preferential escape of gas and leaving mostly oil accumulations. The seal is considered the largest risk in this play. **Note**: At the time of this assessment, the Topset play was not considered to be of significance and was later re-evaluated in subsequent assessments.

2. **Turbidite play.** This play consists of stratigraphic traps in deep-marine sandstone reservoirs of Late Cretaceous and Tertiary age that occur in the foreset and bottomset within the Canning Formation. The play is limited to the northwestern part of the 1002 Area, which is largely unaffected by the folding and thrusting of the Brooks Range. The maximum thickness for rocks in this play is about 5,000 feet and drilling depths range from 4,000 feet to 22,000 feet. The sandstone bodies are expected to be laterally discontinuous with an aggregate thickness of several hundred feet, with several stacked individual beds thought to be less than 50 feet thick. Abnormally high fluid pressure is expected (based on well data to the west of ANWR), indicating that porosities should be higher than those normally encountered in turbidite sandstones at these depths. Both oil and gas have been recovered from turbidite reservoirs immediately to the west of the 1002 Area boundary and generally consist of 21° to 27° American Petroleum Institute (API) gravity but can be as high as 44° API gravity, as indicated by a drill stem test that recorded a rate of 2,500 barrels of oil per day (BOPD). Faults and the encasement of marine shales are expected to provide fair to good seals.

3. **Thomson-Kemik Play**. This play consists of stratigraphic traps in sandstone reservoirs of Early Cretaceous (Neocomian) age. The Kemik Sandstone is correlative to the Thomson Sandstone (local name usage). This play is limited to the northwestern part of the 1002 Area and is generally unaffected by the Brooks Range folding and faulting. The sandstone overlies the Lower Cretaceous Unconformity (LCU) and was deposited in a shallow-marine to possibly a nonmarine depositional environment. Drilling depths range from 12,000 feet to 25,000 feet, with thicknesses expected to reach up to 345 feet. Wells drilled directly west of the 1002 Area boundary, in what is now known as the Point Thomson field, have penetrated these sandstones. Average porosity is estimated at about 12 percent, but abnormally high fluid pressure may result in higher-than-average porosity compared to similar sandstones at this depth. Postulated traps in this play are thought to be stratigraphic, although structural traps may also occur against small-displacement normal faults. Both oil and gas are present in the Thomson sand in the Point Thomson field which contains reserves of 5 trillion cubic feet of gas and 375 million barrels of condensate (as of the time of this assessment). Flow rates are reported to be as much as 13 million cubic feet of gas per day and 2,283 BOPD with an oil gravity of 35° to 45° API gravity but some oil gravity has been reported as low as 18° API gravity. Faults and the overlying thick marine shales are expected to provide fair to good seals.

4. **Undeformed Pre-Mississippian Play**. This play consists of stratigraphic traps in carbonate or sandstone reservoirs in the Pre-Mississippian basement complex. In general, Pre-Mississippian rocks were metamorphosed, folded, faulted, uplifted, and eroded throughout the 1002 Area. However, the northwest corner of the 1002 Area was largely unaffected by the Brooks Range

folding and faulting. The transition between the deformed and undeformed pre-Mississippian rocks lies slightly north of the MCA. Drilling depths are expected to range from 12,000 feet to 24,000 feet. The occurrence of reservoir rocks in the basement complex is unpredictable. Potential reservoir rock may consist of dolomite, limestone, and sandstone. Outcrops of the Katakturuk Dolomite suggest it may be vuggy, and under favorable conditions, leaching of calcareous cements may improve reservoir rocks in the subsurface. Additionally, fractures are expected in this rock and should enhance the observed low-matrix permeabilities. Although the carbonate rocks may have local porosities as high as 25 percent, the expected average porosity for the entire thickness is only about 10 percent. Flow rates observed from this play in the Alaska State F-1 well were about 150 BOPD of 35° API gravity and 3 thousand cubic feet per day (MCFPD) gas. Saltwater was also observed in the Alaska State A-1 with flow rates of 4,220 barrels of water per day (BWPD), and fresh water was observed in Canning River Unit A-1 with a rate of 4,800 BWPD.

5. **Imbricate Fold Belt Play**. This play is in the deformed zone and consists primarily of structural taps in Cretaceous and Tertiary-aged rocks. These traps, which consist of numerous fault-cored anticlines, are the result of the Brooks Range folding and faulting and encompass the area southeast of the line, marking the limit along the northern flank of the MCA. Sandstone reservoirs may consist of the Kemik Sandstone, Canning Formation Turbidites, and the Sagavanirktok Formation deltaic deposits (topsets of the Brookian Megasequence). Drilling depths in this play are expected to range from 100 feet to 26,00 feet. Turbidite reservoirs are expected to be the most prospective in this play. The Kemik Sandstone is less prospective in this play because of its unpredictable occurrence. The topsets are expected to have excellent reservoir quality; however, the seal integrity remains uncertain. Also included in this play are the very poor reservoir sandstones and conglomerates of the Jago River Formation in the southeastern part of the area. Potential source rocks include the Kingak Shale, Pebble Shale Unit, Hue Shale, and Canning Formation. The Canning Formation is expected to be a poor source rock, while the Jurassic (Kingak) and Cretaceous shales (Hue Shale and Pebble Shale Unit) are expected to be fair to good source rocks.

6. **Folded Ellesmerian/Pre-Mississippian Play**. This play consists mostly of structural traps in sandstone or carbonate reservoirs of Pre-Mississippian to earliest Cretaceous age, resulting from the Brooks Range folding and faulting. This play underlies nearly the same areas as the Imbricate Fold Belt play and lies southeast of the transition area, southeast of the northern limit of the MCA. Reservoirs consist mainly of Ellesmerian and Pre-Ellesmerian rocks but may include some Brookian rocks. Carbonate rocks include the Katakturuk Dolomite, Nanook Limestone, other unnamed pre-Mississippian carbonates, the Lisburne Group, and the Shublik Formation. Sandstone rocks consist of Pre-Mississippian sandstone, Kekituk Conglomerate, Echooka Formation, Ivishak Formation, Karen Creek Sandstone, Kemik Sandstone, and possibly turbidite sandstones in the basal part of the Brookian sequence. The Ivishak Formation (Ledge Sandstone Member) is considered the most important sandstone reservoir while the Lisburne Group and Katakturuk Dolomite are considered the most important carbonate reservoirs. The areal distribution of these reservoirs is unknown because of the regional LCU in which erosion has removed an undetermined number of underlying strata. Outcrop information indicates these rocks

are present and plunge into the subsurface. However, the northern extent is unknown and depend on several factors, including the rate of truncation of the unconformity, the amount of northward transport by thrust faulting, and the possible existence of down dropped fault blocks north of the truncation edge. Drilling depths range from 2,000 feet to 25,000 feet. Traps are considered to be mostly structural and consist of few but relatively large and broad anticlines and fault traps. Stratigraphic traps related to truncation by the LCU are also possible. The Pebble Shale Unit and younger shales are expected to provide good to excellent seals. However, the presence of oil seeps and oil-stained sandstones in the play area suggests that some traps in this play, or the overlying Imbricate Fold Belt play, may be leaking. Seismic mapping identified two extremely large structures (structures 18 and 19, as shown in Figure 5-3). These structures were given special consideration regarding their position relative to the Ellesmerian truncation edge and the relationship between the trap fill and hydrocarbon column height.

7. **Undeformed Ellesmerian Play**. This play consists of stratigraphic traps in carbonate and sandstone reservoirs in the Ellesmerian sequence. This play is limited to the northwestern part of the 1002 Area, which is unaffected by the Brooks Range folding and faulting. A wedge of Ellesmerian rocks has been seismically mapped beneath the LCU in the southwestern most corner of the play area. Additionally, fault-bounded, down-dropped blocks that preserve Ellesmerian rocks, similar to those identified in the Prudhoe Bay area., may exist; however, they have not yet been confirmed within the 1002 Area. Potential reservoirs consist of both sandstone and carbonate, with the most significant being dolomites in the Lisburne Group and the Ledge Sandstone Member of the Ivishak Formation. Reservoir properties may improve near the LCU, as observed in Prudhoe Bay. Average porosity is expected to be about 4 percent for carbonates and 15 percent for sandstones. Possible traps are likely stratigraphic, relying on younger marine shales for seals.

6.1.1.1 Estimates of Oil-In-Place

The estimates of OOIP and original-gas-in-place (OGIP) are in the form of complementary cumulative probability distributions. Table 6-2 provides the estimates between the 95th and 5th percentile probabilities. These estimates are distributed regionally into the northwest and the southeast sectors, which correspond to the "undeformed zone" and "deformed zone," respectively. The northwest sector, representing the "undeformed zone," encompasses about one-third of the 1002 Area, while the southeast sector, representing the "deformed zone," covers about two-thirds of the 1002 Area. The axis of the MCA serves as the boundary between the two sectors. The northwest sector includes the following plays: (1) topset, (2) turbidite, (3) Thomson-Kemik, (4) undeformed pre-Mississippian, and (7) undeformed Ellesmerian. The southeast sector includes the following plays: (5) imbricate fold belt, and the (6) folded Ellesmerian/pre-Mississippian.

Table 6-2 Summary of In-Place Oil and Gas Resources in the ANWR 1002 Area

Area	F95	Mean	F05
Northwest Sector (plays 1-4 and 7)			
Oil (BBO)	0.9	3.6	8.7
Nonassociated Gas (TCFG)	1.0	4.6	11.9
Total Gas (TCFG)	3.0	8.4	17.8
Southeast Sector (plays 5 and 6)			
Oil (BBO)	2.7	10.3	24.7
Nonassociated Gas (TCFG)	1.7	12.2	36.3
Total Gas (TCFG)	6.2	22.9	54.4
Total ANWR 1002 Area			
Oil (BBO)	4.8	13.8	29.4
Nonassociated Gas (TCFG)	3.7	16.7	43.6
Total Gas (TCFG)	11.5	31.3	64.5

Key: F95 = 95th fractile; F05 = 5th fractile; TCFG = trillion cubic feet of gas; BBO = billion barrels of oil
Source: USGS (1987)

Note that the in-place oil and gas were differentiated by regional areas and not by play type (Figure 6-1 and Table 6-1). Furthermore, this assessment was conducted in the mid-1980s; since then, additional well data and field discoveries have been made, furthering the understanding of the hydrocarbon potential in this area. For example, this study did not take into consideration the role the topsets have played in recent years. Major field discoveries have been made in the Brookian sequence including the Pikka field, Willow field, Hammerhead, and most recently (2024) the Armstrong/Lagniappe wells (also known as BP's Courage and Kirin prospects) near the southwestern boundary of the Point Thomson field, which is near the western boundary of the 1002 Area. At the time of this assessment, younger strata within the Brookian sequence were thought to be less prospective and structural plays were thought to be most prospective, yielding the highest returns in recoverable oil and gas. However, similar wells have been drilled in the Brooks Range foothills elsewhere on the North Slope with little success.

6.2 1998 USGS Assessment

The purpose of the *1998 USGS Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, Including Economic Analysis*, was to update the economics of the 1002 Area because additional geological data became available since the 1987 USGS Bulletin 1778 resource assessment. After the 1987 assessment, several wells were drilled, leading to numerous oil field discoveries near the 1002 Area, including Hammerhead, Kuvlum, Badami, and Sourdough. Seismic processing and interpretation were also improved at the time of the 1998 report. The assessment involved 3 years of studies conducted by

approximately 40 USGS scientists, who coordinated work with the other federal agencies, Alaska state agencies, and several universities. New field studies were conducted, new well and sample data were analyzed, and the 1984 and 1985 seismic data were reprocessed and interpreted. Acquiring new seismic data was not allowed at the time because it required an act of Congress; however, with the passage of the 2017 Tax Act , acquiring new seismic data should now be permitted.

One of the key differences between the 1987 USGS Bulletin 1778 and this report is the modification of play types, increasing the number from seven to ten. A play is defined as a volume of rock that contains similar geological characteristics that determine petroleum potential. Additionally, the total play area considered was expanded to include the 3-mile boundary between state and federal jurisdiction (a 3-mile buffer off the 1002 Area coastline) and Native lands belonging to KIC/ASRC. Another notable difference is that the 1987 assessment volumes were reported as oil-in-place, whereas the 1998 assessment volumes are reported as technically recoverable oil.

The ten plays include the following: (1) topset, (2) turbidite, (3) wedge, (4) Thomson, (5) Kemik, (6) undeformed Franklinian, (7) deformed Franklinian, (8) thin-skinned thrust-belt, (9) Ellesmerian thrust-belt, and (10) Niguanak-Aurora. Detailed descriptions are available in the USGS (1998) Open File Report 98-34 but are briefly summarized below and are divided into the undeformed and deformed structural regimes.

6.2.1 Undeformed Area

- Topset Play – This play includes seismic facies identified within the Paleocene through Miocene strata in the undeformed part of the 1002 Area. Topset facies include marine shelf, deltaic, and nonmarine sedimentary rocks based on the analysis of 2-D reprocessed seismic data, outcrops, wireline logs, and cores. Sandstones within the Topset play have some of the best reservoir quality in the 1002 Area. Based on inferred depositional environments, potential reservoir rocks are likely to be lenticular in nature. Present day analogs are Pikka and Willow.
- Turbidite Play – This play includes the turbidites in the Brookian (Canning Formation) slope and basin floor. The reservoirs are channel and lobe sandstones of Paleocene to Eocene age and are sourced from the Hue and Canning Formation organic-rich shales. Analogs are Sourdough and Flaxman Island.
- Wedge Play – This play is a combination of the Topset and Turbidite plays. No analogs are known.
- Thomson Play – This play is the eastward extension of the Point Thomson Field and consists of shallow marine sandstones stratigraphically trapped on paleo structural highs and grabens. The oil is sourced from the Hue Shale and from shales in the lower part of the Canning Formation. The analog is the Point Thomson Field.
- Kemik Play – This play is the eastward equivalent of the Thomson Sandstone and is very similar to the Thomson play.

- Undeformed Franklinian Play – This play consists of Franklinian carbonate reservoirs trapped by the Lower Cretaceous unconformity on the flank of the Barrow Arch. The analog is the oil discovered in this section in the Point Thomson Field.

6.2.2 Deformed Area

- Deformed Franklinian Play – This play consists of carbonates reservoirs in anticline and fault traps. The oil would be primarily sourced from the Hue Shale and Shublik Formation. No analogs are known.
- Thin-Skinned Thrust Belt Play – This play consists of Brookian turbidite and topset sandstone reservoirs trapped by anticlines and fault traps. Present day analogs are the Umiat and Gubik fields.
- Ellesmerian Thrust Belt Play – This play consists of sandstone and conglomerate reservoirs in the Ivishak, Sag River, and Kekiktuk Formations, along with carbonates in the Lisburne Group that are trapped by thrusted anticlines and thrust faults. Analogs are the Kavik and Kemik accumulations,
- Niguanak-Aurora Play – This play consists of two large structures in the eastern part of the 1002 Area that were identified as prospects #18 and #19 in the USGS 1987 Assessment. No analogs are known.

Table 6-3 shows the USGS estimated recoverable reserves by play type. Note the Topset play has the most recoverable reserves at 5.8 billion barrels, and the Turbidite play is second with 1.5 billion barrels. Of the total recoverable reserves estimated to be in the 1002 Area, 83 percent of the reserves are the undeformed structural regime (or the northwest part) of the 1002 Area.

Table 6-3 Fractile Estimates of Technically Recoverable Resources Listed by Play in the 1002 Area

Oil play name	Volume of technically recoverable oil (MMBO) fractiles			Number of oil deposits fractiles		
	95th	50th	5th	95th	50th	5th
Topset	2,412.43	5,831.46	11,111.86	12.57	22.19	30.91
Turbidite	492.80	1,484.98	3,111.18	6.14	13.29	21.05
Wedge	0.00	382.41	1,555.78	0.00	2.95	6.76
Thomson	0.00	213.17	1,267.79	0.00	1.67	3.10
Kemik	0.00	0.00	289.61	0.00	0.00	4.95
Undeformed Franklinian	0.00	0.00	452.84	0.00	0.00	2.43
Thin-Skinned Thrust-Belt	0.00	929.68	3,176.07	0.00	4.91	6.52
Niguanak-Aurora[1]	0.00	166.51	1,436.84	--	--	--
Gas play name	**Volume of technically recoverable non-associated gas (BCFG) fractiles**			**Number of non-associated gas deposits fractiles**		
	95th	50th	5th	95th	50th	5th
Deformed Franklinian[2]	0.00	0.00	5,382.45	0.00	0.00	1.67
Ellesmerian Thrust-Belt	0.00	277.42	3,659.76	0.00	1.00	1.76

[1] Aggregate of two-dome and many-prospect scenarios.
[2] Twenty percent of the accumulations are oil.

Source: USGS (1998).

6.3 2005 USGS Update

The USGS 2005 assessment serves as an economic update to the 1998 USGS assessment. For the 2005 update, the USGS developed a full-cycle cost function to predict the volume of oil that is economically recoverable at a given market price, expressed in 2003 dollars. The assessment includes several assumptions, such as the use of highly efficient horizontal production wells and the expectation that larger fields would shoulder the economic burden during the initial stages of development, with satellite fields becoming more important later. No changes were made to the geological evaluation compared to the 1998 assessment. Estimates of technically recoverable oil in undiscovered accumulations in the 1002 Area range from 4.25 billion barrels of oil (BBO) to 11.80 BBO, with a mean of 7.69 BBO (Table 6-4), which is the equivalent to about one-third to one-half of the greater Prudhoe Bay field. The updated reserves estimate for the Topset play is 3.7 BBO, compared to 5.8 BBO in the 1998 assessment, while for the Turbidite play, the estimate is 1.3 BBO in 2005, compared to 1.5 BBO in 1998.

Table 6-4 USGS 2005 Reserves Evaluation Update

Area/Play Name1	Oil Fields			Gas Fields	
	Oil (BBO)	Gas (TCF)	NGL (BBL)	Gas (TCF)	NGL (BBL)
Western sub-area					
Topset	3.707	1.022	0.008	0.000	0.000
Turbidite	1.279	1.120	0.065	0.000	0.000
Wedge	0.438	0.226	0.005	0.000	0.000
Thomson	0.246	0.314	0.026	0.156	0.013
Kemik	0.047	0.060	0.005	0.056	0.005
Undeformed Franklinian	0.085	0.150	0.015	0.150	0.014
Thin-Skinned Thrust Belt	0.288	0.079	0.001	0.368	0.004
Ellesmerian	0.000	0.000	0.000	0.088	0.002
Deformed Franklinian	0.041	0.040	0.003	0.734	0.039
Subtotal	6.132	3.011	0.129	1.551	0.076
Eastern sub-area					
Topset	0.618	0.170	0.001	0.000	0.000
Thin-Skinned Thrust Belt	0.750	0.205	0.002	0.957	0.010
Ellesmerian Thrust Belt	0.000	0.000	0.000	0.788	0.016
Deformed Franklinian	0.005	0.004	0.000	0.082	0.004
Niguanak/Aurora	0.183	0.168	0.010	0.105	0.006
Subtotal	1.555	0.548	0.014	1.931	0.036
Total Federal 1002 Area	7.687	3.558	0.143	3.483	0.112

Source: USGS (2005)

7.0 PROMISING PLAY TYPES IN AREA 1002 UNDEFORMED AREA

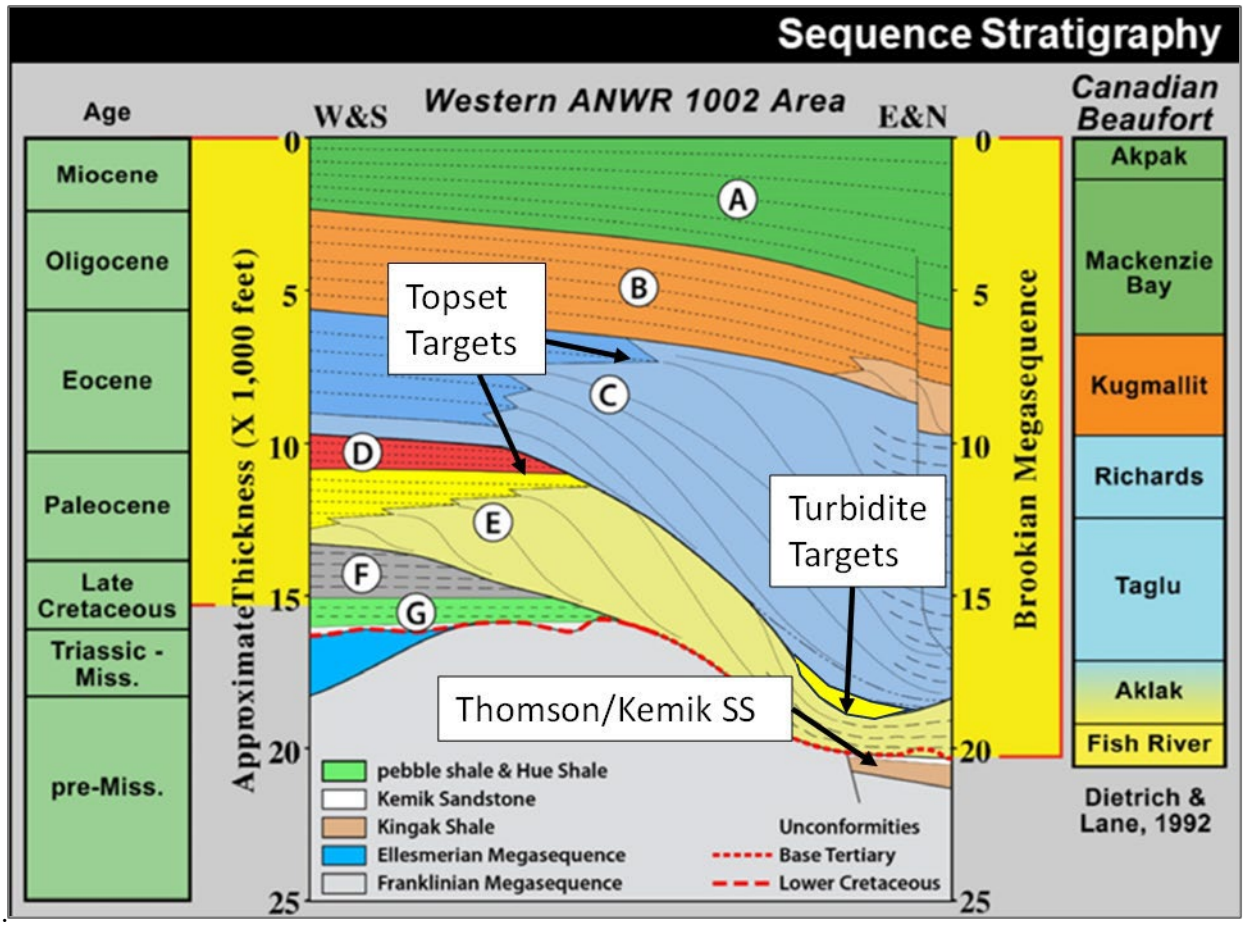
Combining the USGS petroleum assessments with the exploration and development activity in the central North Slope, three play types in the 1002 Area are considered the most promising. Ranked in order, they are the Topset, Turbidite, and Thomson-Kemik Sandstone (Figure 7-1 and 7-2). The Turbidite and Thompson/Kemik Sandstone plays are proven just to the west of the 1002 Area.

The Topset play consists of deltas that formed along the on the shelf along the coastline (Figure 7-3). These are stratigraphic traps that pinch out up-dip and have a flooding shale as the top seal.

The Turbidite play comprises turbidite channels and fans that were deposited on the slope and basin floor (Figure 7-3). Stratigraphic traps are incased in slope and basin shales. The play most likely extends further into the 1002 Area, but 3-D seismic data are crucial for detecting and delineating it.

The Topset play has shown the most recent promise in the central North Slope area, with exploration leading to the Pikka and Willow discoveries. The reservoirs in the Topset play are of better quality than those in the Turbidite play. Both require 3-D seismic data to detect and delineate the plays. Figure 7-3 shows the stratigraphic relationship of the Topset play to the Turbidite play. The Thomson Sandstone, which serves as the producing reservoir in the Point Thomson Field, may extend slightly eastward into the 1002 Area. The stratigraphically equivalent Kemik Sandstone may also extend into the 1002 Area, though it is likely to be gas prone.

Figure 7-1 Sequence Stratigraphy of the ANWR 1002 Area and the Play Types



Source: Modified from Houseknecht (2019)

Figure 7-2 Diagrammatic Cross Section Showing the Relationship of the Apache/Lagniappe Wells and the Point Thomson Area

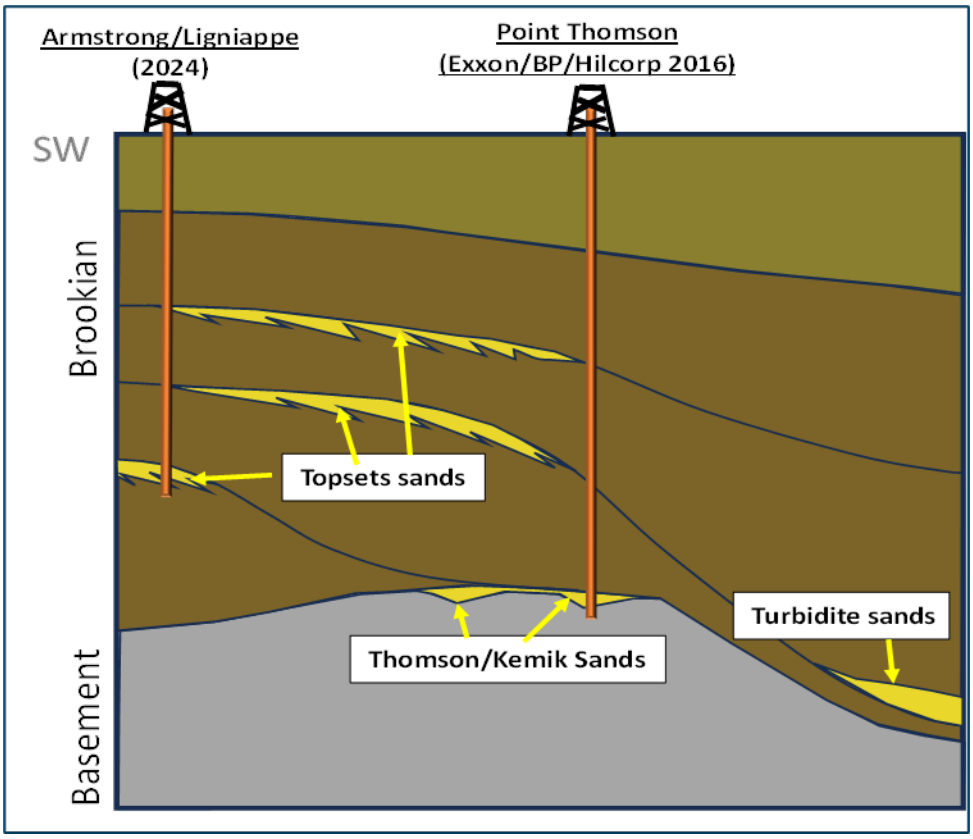
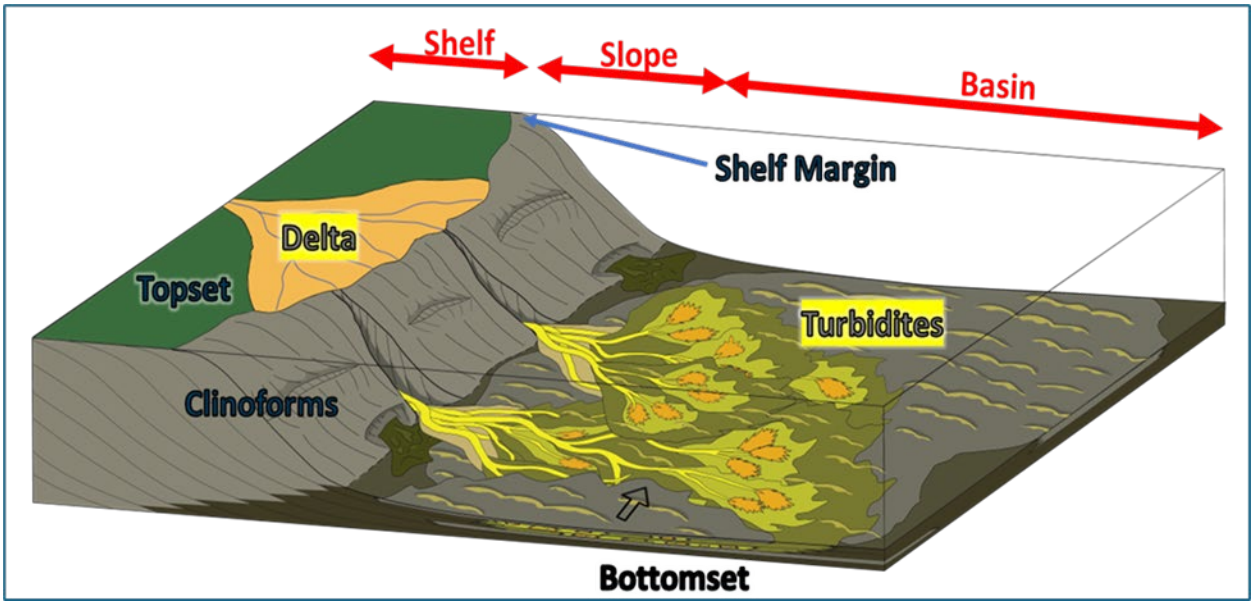


Figure 7-3 Topset and Turbidite Depositional Model



Source: Modified from Jones (2023)

7.1 Topset Play

7.1.1 Description

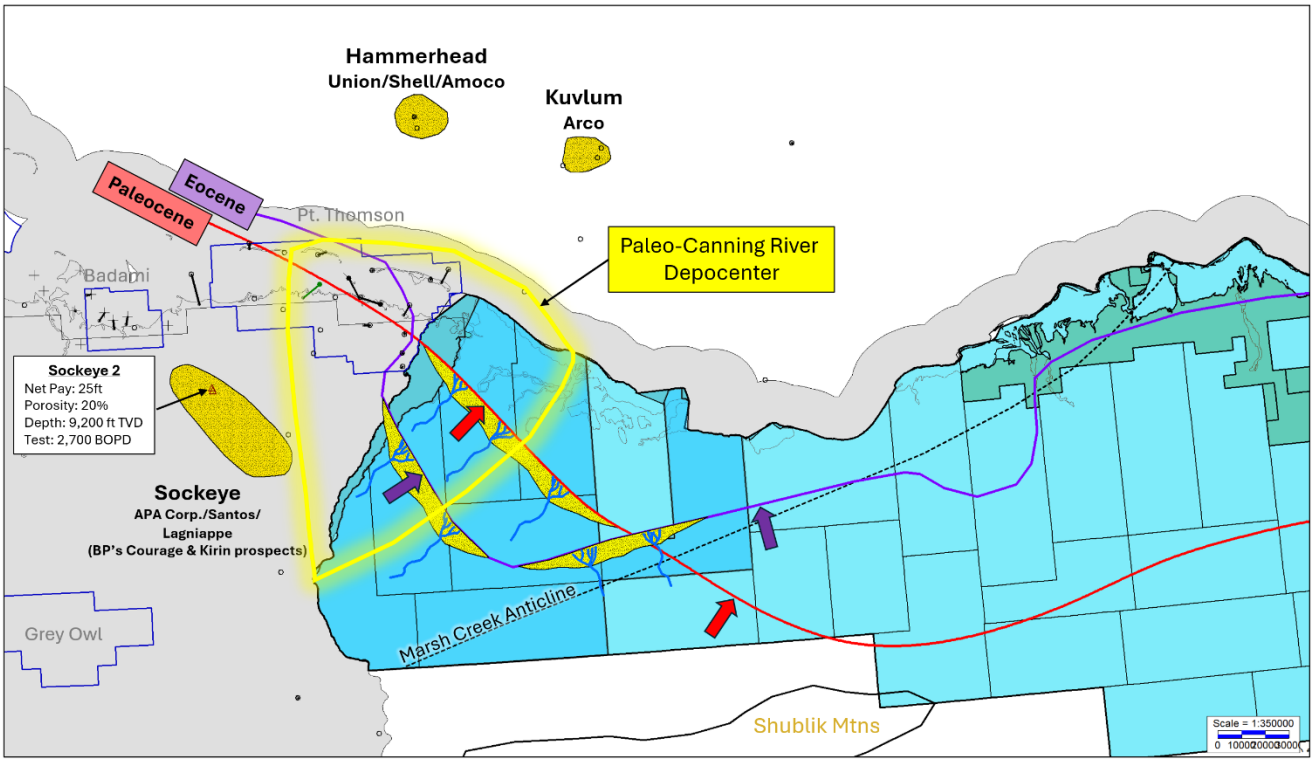
Figure 7-4 is a map showing the Topset play in the 1002 Area. This play is a younger analog to Pikka (Santos), Willow (ConocoPhillips), West Sak/Ugnu (ConocoPhillips/Hilcorp) fields, and the Sockeye discovery by Apache Corporation (subsidiary of APA Corporation) and its partners Lagniappe (an Armstrong company) and Oil Search (a subsidiary of Santos Ltd.) (Figure 7-4).

The Topset play is older in age than the Hammerhead (Union/Shell/Amoco) and Kuvlum (Arco) offshore discoveries. The paleo-Canning River sand depositional center (i.e., depocenter) spread across to the east and west from the existing Canning River. More good sands are expected in the western part of the 1002 Area due to the long-standing depocenter.

Oil for this play type would be sourced from Hue Shale and Canning Formation (potential Shublik Formation contribution). Petroleum system modeling indicates that this play could be charged with medium to light gravity oil. The reservoirs are marine shelf, deltaic, and fluvial sandstones of Paleocene to Eocene in age. The average porosity of these sandstones in the area to the west ranges from 20 percent to 25 percent, with an average thickness of 150 feet. The target depth range is 7,000 feet to 11,000 feet. 3-D seismic data are necessary to detect and delineate this play type.

In 1998, the USGS estimated a mean value of 15.45 BBO OOIP for the entire Topset play and 6.18 BBO in technically recoverable reserves. In 2005, the USGS revised the recoverable reserves to 3.7 BBO. We interpret that more than 80 percent of the USGS's Topset play falls within our focus area. Therefore, our focus area would contain 3 to 5 BBO of recoverable reserves. This compares to the Nanushuk at Pikka and Willow, with an estimated combined recoverable of about 2 billion barrels.

Figure 7-4 Topset Play Map with Hypothetical Shelf Margin Depositional System



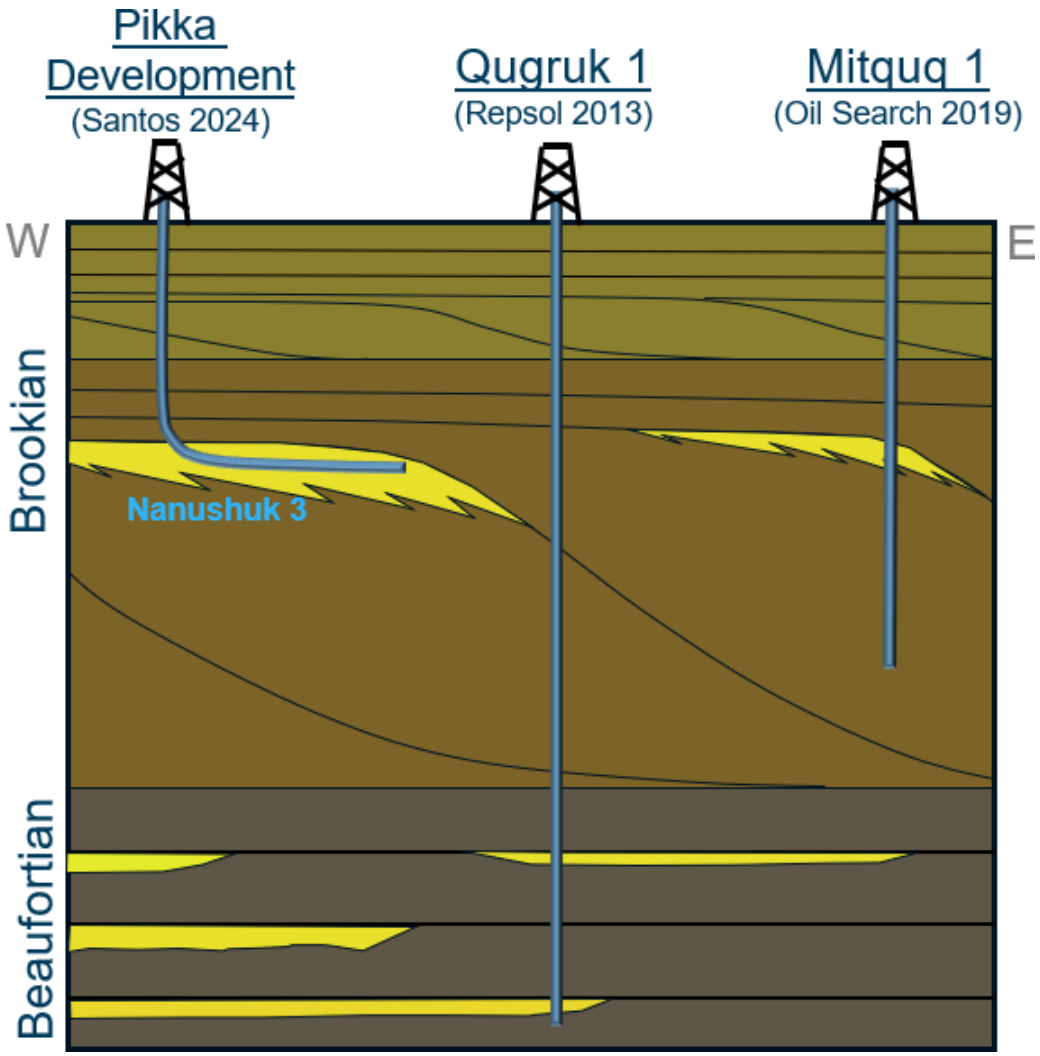
Notes: Topset play map showing the Paleocene and Eocene shelf margins as interpreted by Houseknecht (2019) with a hypothetical shelf margin depositional system, the conceptual paleo-Canning River depocenter, and exploration discoveries and activities.

7.1.2 Analogs

7.1.2.1 Nanushuk (Pikka, Willow, Horseshoe)

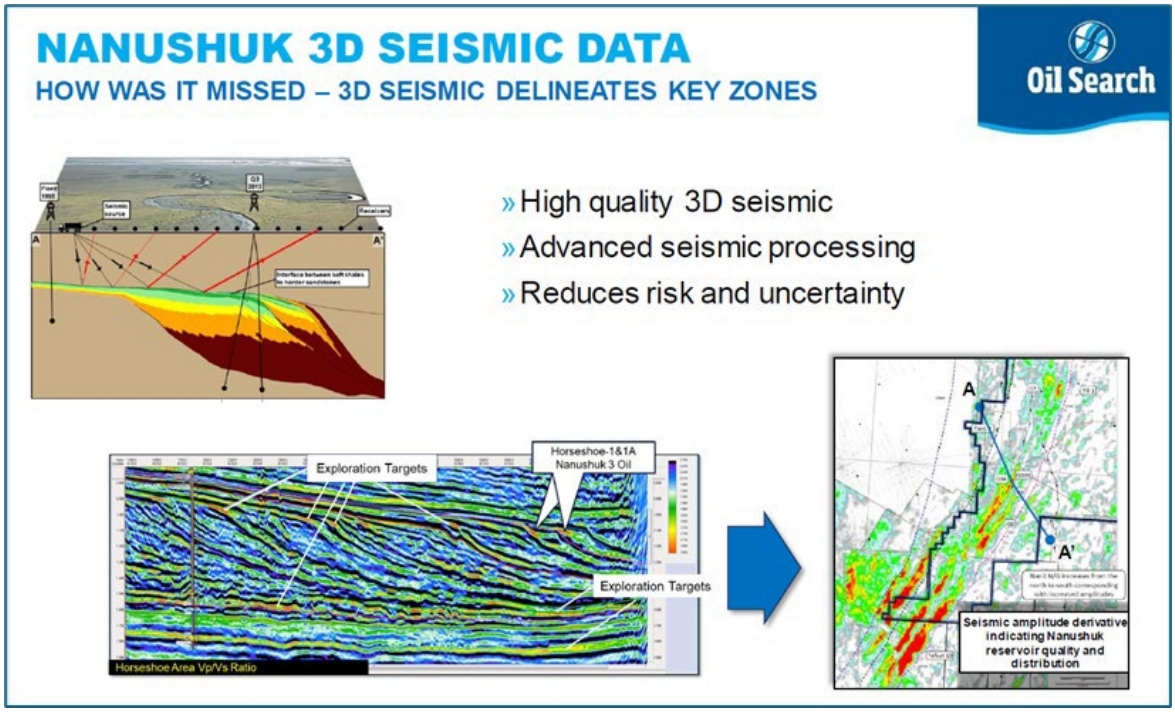
In 2008, Armstrong Oil and Gas (AOG) initiated seismic licensing over what is now known as the Pikka Unit. The acquisition of 3-D seismic data over this area took place between 2010 and 2015. In 2011, Repsol farmed into AOG's acreage position, and the Nanushuk 3 play fairway (a nomenclature adopted by AOG) was discovered in 2013 with the drilling of the Qugruk #3 well. Many exploration wells had been drilled in this area, targeting deeper prospects on the Colville High, but they missed the Nanushuk oil reservoir, which lies at a depth of around 4,000 feet (Figure 7-5). AOG used shows observed in these earlier wells, along with amplitude anomalies mapped in the 3-D seismic data, to lead to the Nanushuk 3 discovery (Figure 7-6). This discovery opened a new play type on the North Slope, which now includes the Willow Field within the Moose's Tooth Unit (located within the National Petroleum Reserve – Alaska [NPR-A]), the extended Nanushuk 3 trend into the Horseshoe Unit, and exploration wells drilled south of the Badami Unit (Apache/Lagniappe).

Figure 7-5 Diagrammatic Cross Section Showing the Nanushuk 3 Topset Trend



Note See Table 2.

Figure 7-6 How the Pikka Topset Play Was Discovered.



Source: RDC (2019)

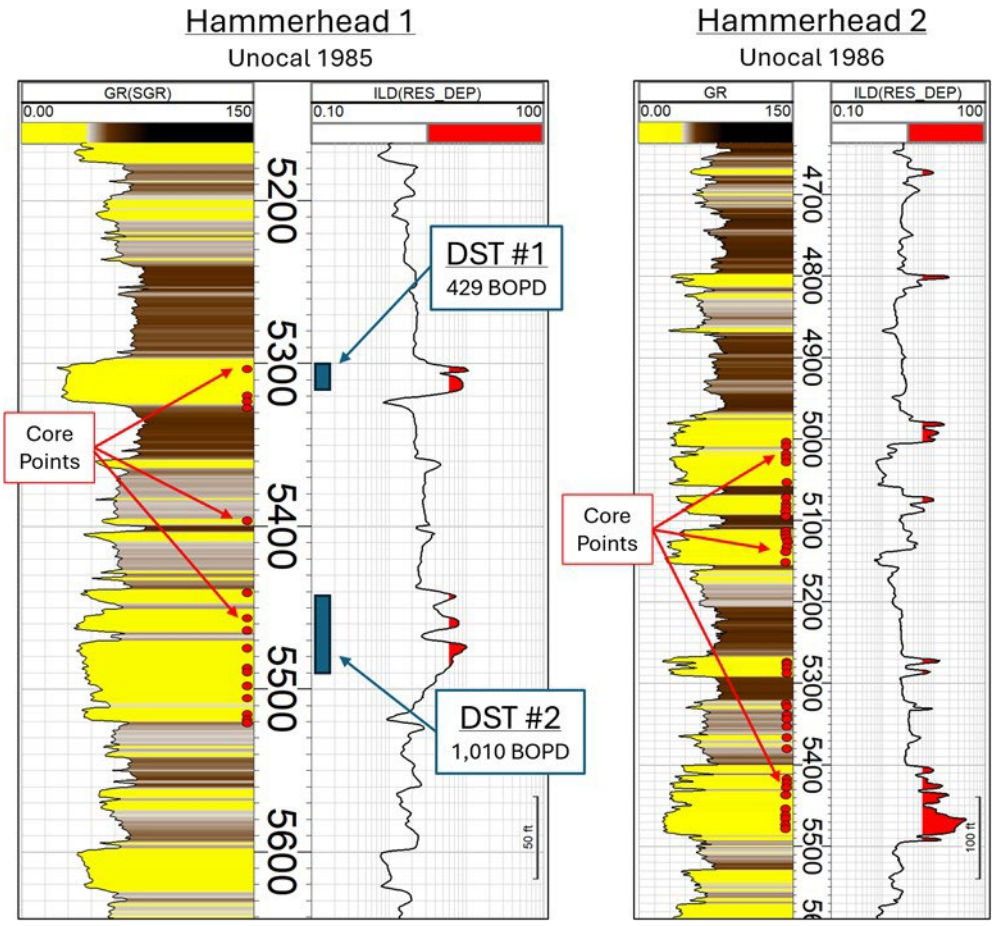
7.1.2.2 Hammerhead

The Hammerhead prospect, a late Oligocene Brookian topset, was identified and drilled offshore approximately 13 miles north of Point Thomson Unit by Union Oil Company of California (UNOCAL) in 1985. This was done near the Hammerhead #1 well (OCS Y-849-1). Digital log data and mudlog data show that the well encountered multiple stacked sandstone units, interpreted as deltaic and fluvial sediments, starting from the surface (Pliocene) to about 6,300 feet true vertical depth (TVD) (early Oligocene). This evidence supports the idea that a long-standing depositional source existed in this area (i.e., paleo-Canning River depocenter).

Multiple hydrocarbon bearing reservoirs (Figure 7-7) were encountered between 5,300 feet and 5,550 feet measured depth (MD). Four sand packages were evaluated with sidewall cores and two drill stem tests (DSTs). The core points are shown on Figure 7-7. Core analysis for these points show that porosities range from 28.4 percent to 41.2 percent, with an average of 33.3 percent, and that permeabilities range from 83 millidarcies (mD) and 2,450 mD, with an average of 508.8 mD. The two DSTs were conducted in two intervals. DST # 1 was tested in the interval 5,442 feet to 5,490 feet MD at a rate of 429 BOPD, 579 BWPD, and 14 BSPD. DST # 2 was tested in the interval of 5,300 feet to 5,315 feet MD at a rate of 1,010 BOPD and 64 BWPD. Oil gravity is 20° API.

The following year, in 1986, Hammerhead #2 (OCS Y-849-2) was drilled and had similar results to Hammerhead #1, showing multiple stacked deltaic and fluvial sediments through the entirety of the well. Multiple hydrocarbon-bearing reservoirs were encountered, starting from 4,660 feet MD to TD 6,460 feet MD. Sidewall cores (Figure 7-7) were taken, and the analysis shows porosities range from 25.4 percent to 40.5 percent, with an average of 33.1 percent; permeabilities range from 3.3 mD to 3570, mD with an average of 514 mD. The well was not tested.

Figure 7-7 The Hammerhead #1 and #2 Wells Show Log Character of the Topset Sands with DSTs and Sidewall Core Intervals



Key:
DST = drill stem test

7.1.2.3 Sockeye Discovery

The Sockeye discovery was made in the winter season of 2024-2025 by the Sockeye 2 well in a Paleocene-aged sand located approximately 15 miles west of the 1002 Area boundary (Figure 7-4). This well follows the success of the King Street 1 well drilled the previous winter season further west and encountered two separate oil zones within the Brookian topset (APA Corporation 2025a). The Sockeye 1 well was part of the same drilling program as the King Street 1 well but was plugged and abandoned prior to reaching the target zone due to weather and drilling conditions. APA Corporation and its partners went back the following winter season to drill the Sockeye 2 well. It was drilled to a

depth of approximately 10,500 ft and encountered multiple zones of potential pay (APA Corporation 2025a). The Paleocene-aged reservoir encountered high-quality reservoir along a single 25-foot blocky interval at around 9,200 ft TVD with an average porosity of 20% (APA Corporation 2025b). A 12-day production test was performed and yielded an average of 2,700 BOPD without artificial lift (APA Corporation 2025b). APA Corporation (2025b) stated in their press release that, "The results of the flow test indicate significantly higher reservoir quality compared to similar topset discoveries to the west." In an earlier press release by APA Corporation (2025a), it was released that the Sockeye prospect is supported by an amplitude across 25,000 to 30,000 acres. Additional zones of potential pay were also encountered in the Staines Tongue Formation, a shallower Brookian topset play. This information is of key importance as it is the closest analogue discovery of a Paleocene-aged topset near ANWR and may further derisk the potential for oil in a Paleocene-aged shelf margin mapped by the USGS within ANWR 1002 Area using the 2D seismic data.

7.2 Turbidite Play

7.2.1 Description

Figure 7-8 is a map showing the Turbidite play in the western 1002 Area. The analogs for the Turbidite play are the Sourdough (BP/Hilcorp) and Flaxman Island (Exxon/Hilcorp) discoveries in the Point Thomson Unit. It is also similar to the undrilled prospects in the Point Thomson Unit and to the targets of

Pantheon's and 88 Energy's exploration wells south of Prudhoe Bay. Turbidite sands will be thicker, have better reservoir quality, and may have multiple stacked reservoirs if located within the paleo-Canning River depocenter, as shown on Figure 7-7. Oil for this play type, similar to the Topset play, would be sourced from the Hue Shale and Canning Formation with the potential of some Shublik Formation contribution. The reservoirs are composed of turbidite channels, overbank deposits, and lobe facies of Paleocene to Eocene in age. The analogs have an average porosity of 18 percent with an average thickness of 120 feet. The target range depth is 9,000 feet to 14,000 feet. 3-D seismic data are necessary to detect and delineate this play type. In 1998, the USGS estimated 5.33 BBO OOIP for the entire Turbidite play and 1.6 BBO recoverable. In 2005, the USGS revised the recoverable estimate to 1.3 BBO. We estimate more than 80 percent to be in the focus area, which equates to approximately 1.0 BBO.

7.2.2 Analogs

7.2.2.1 Sourdough

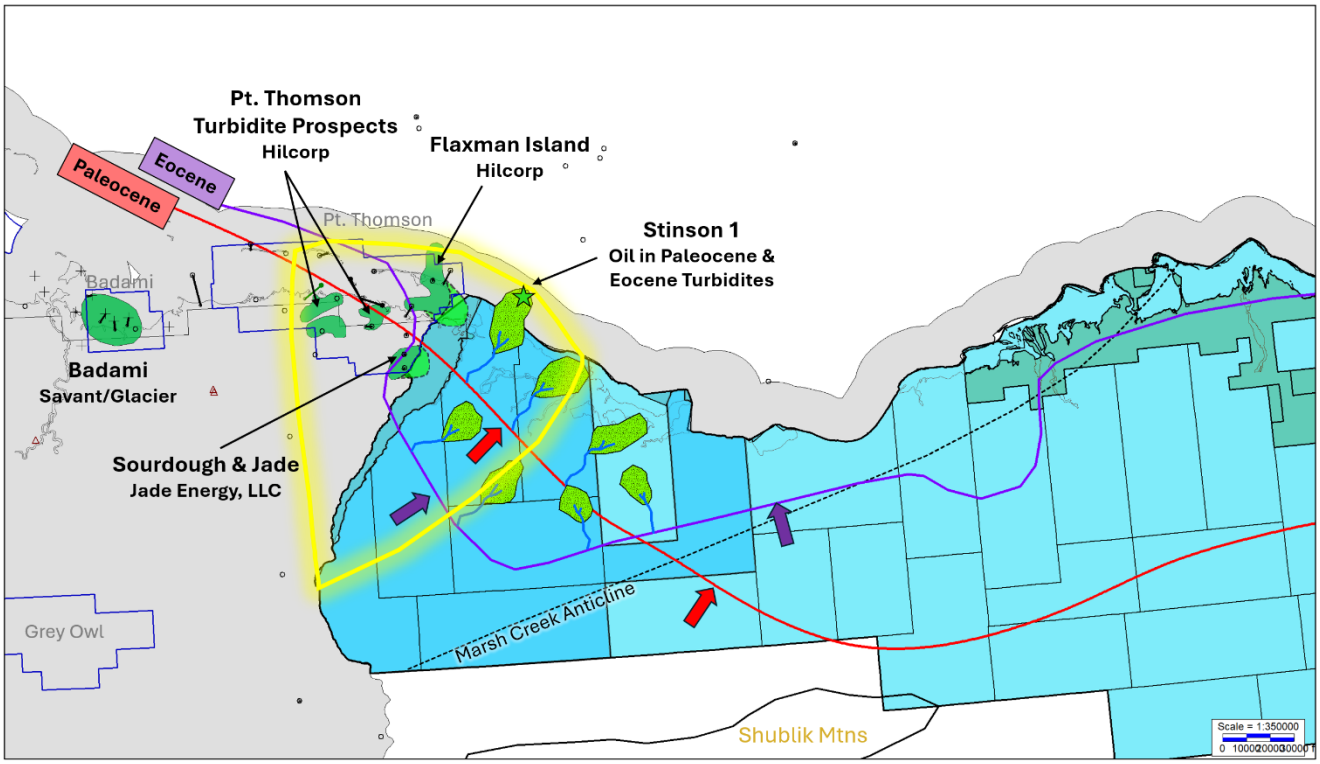
The Sourdough discovery was made by BP with the Sourdough #2 and Sourdough #3 wells drilled in 1994 and 1996, respectively. The wells targeted the Turbidite play in the Canning Formation within the Point Thomson Unit (now operated by Hilcorp) and are located within a half mile to mile from the western boundary of the 1002 Area (Figure 7-9). The Sourdough #2 well encountered approximately four resistive basin floor sediments at depths between 11,420 feet and 12,110 feet MD (11,383 feet and 12,073 feet TVD). The thickest sand body is just under 60 feet (starting at a depth of 11,420 feet MD), while the others are approximately 10 feet thick. Core plugs were taken from the thicker sand body from 11,468 feet to 11,480 feet MD and indicate an average porosity of 13.5 percent and average permeability of 9.18 mD.

The Sourdough #3 well (Figure 7-9) encountered three resistive basin floor sediments at depths between 11,613 feet and 11,943 feet MD (11,603 feet and 11,933 feet TVD). The thickest package of deep-water sediment is approximately 126 feet (starting at a depth of 11,817 MD). The well was tested with an unstimulated rate of 950 BOPD and a stimulated rate of 2,700 BOPD of 27.5° API gravity oil.

7.2.2.2 Flaxman Sandstone

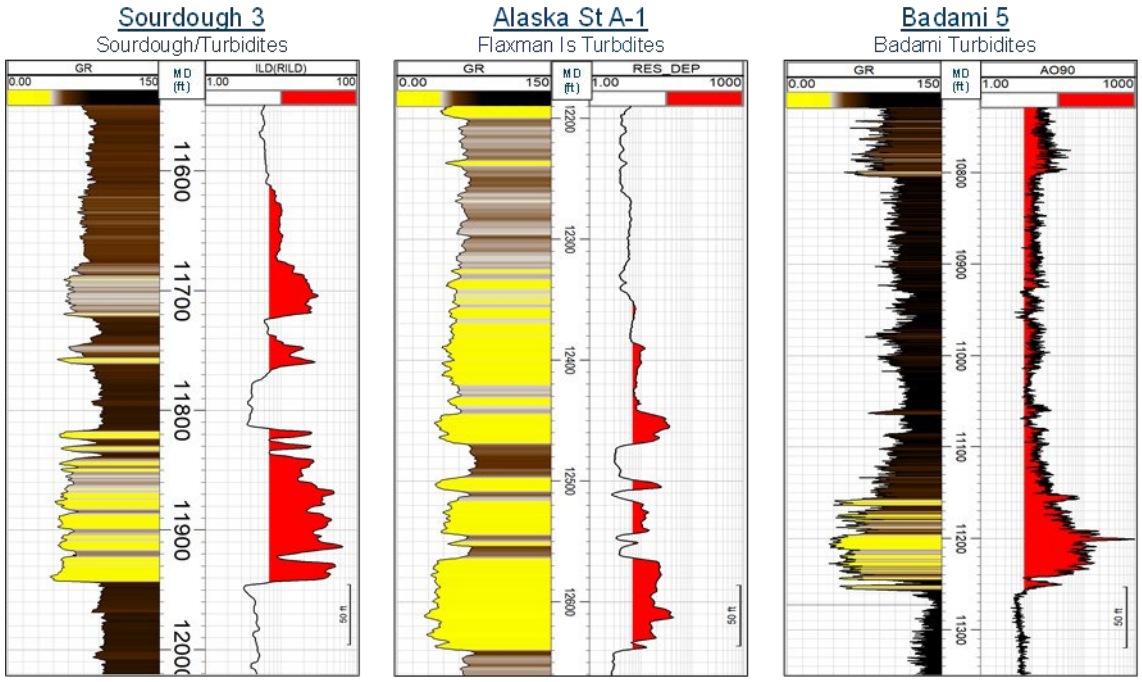
The Flaxman discovery was made in 1975 by Exxon Corporation with the Alaska St A-1 well and is located in the Point Thomson Unit and is located approximately 2.8 miles from the western edge of the 1002 Area (Figure 7-8). The well targeted the Thomson Sandstone but also encountered a thick basin floor sediments with resistivity between 12,351 feet and 12,640 feet MD (12,325 feet and 12,572 feet TVD) as shown on Figure 7-9. This interval was tested with a rate of approximately 2,500 BOPD of 23.1° API gravity oil.

Figure 7-8 Turbidite Play Map



Note: Turbidite play map showing the shelf margin trends as interpreted by Houseknecht (2019) with hypothetical turbidite depositional system from the shelf margin and exploration discoveries and activities.

Figure 7-9 Well Logs of the Turbidite Discoveries and Fields



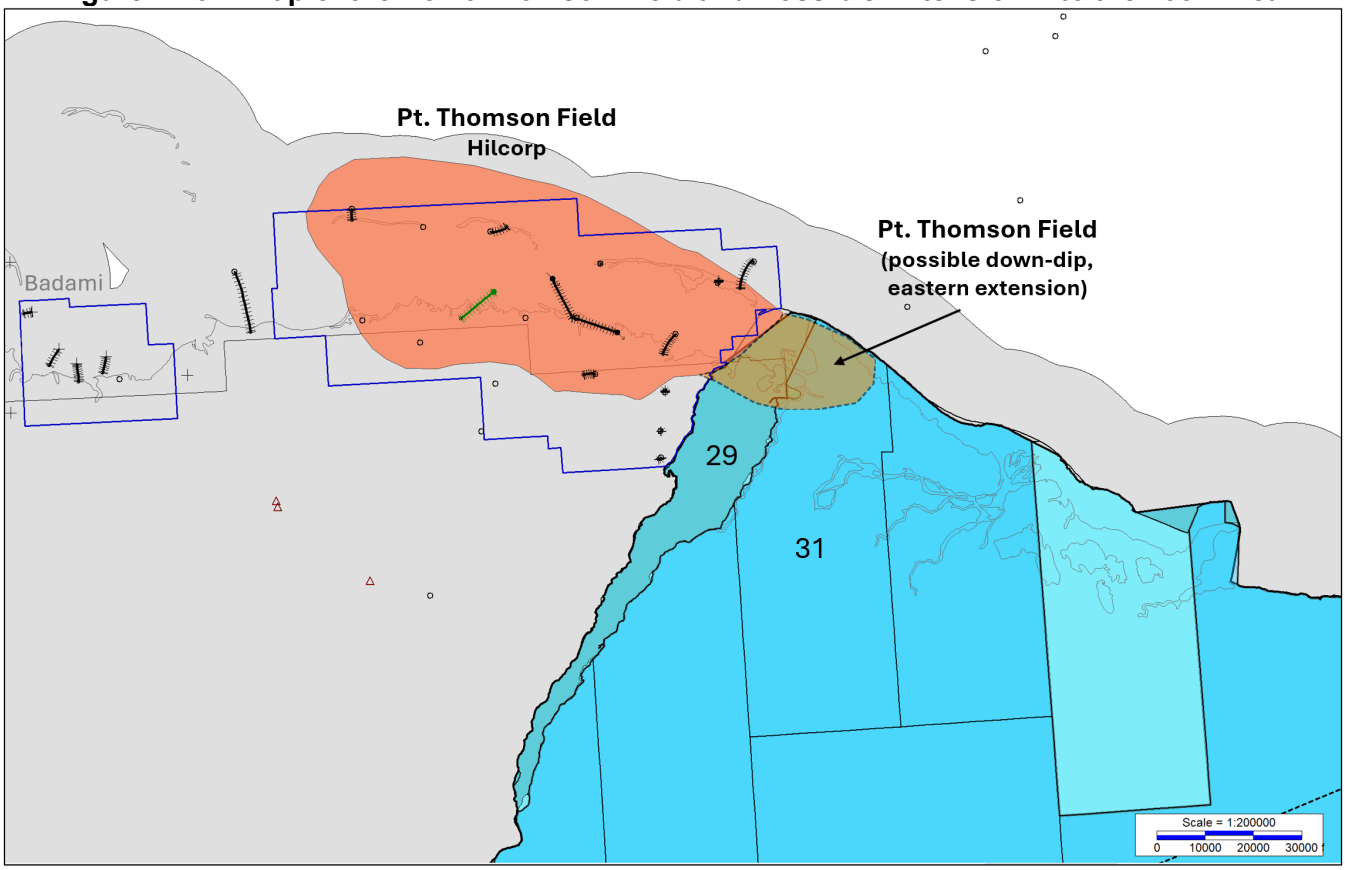
7.3 Thomson-Kemik Sandstone Play

7.3.1 Description

The Thomson and Kemik Sandstones are stratigraphically equivalent and were deposited on the major regional LCU. These sandstones developed in paleo-lows that were created by both extensional faulting and erosional downcutting. A major paleo-low, formed by an extensional graben, created the thick Thomson Sandstone accumulation that defines the Point Thomson field. The eastern flank of the Point Thomson Field extends into ANWR leases 29 and 31 (Figure 7-10). The Thomson Sandstone ranges in depth from 12,800 feet to 13,100 feet and is overpressured. The field produces gas condensate with an API gravity of 35° to 45° and a gas-oil-ratio (GOR) of 6,000 to 22,000 standard cubic feet per barrel (scf/bbl) (for comparison, the Kuparuk Field average GOR is 500 scf/bbl). The estimated reserves are 300 million barrels of oil (MMBO) and 8 to 9 trillion cubic feet of gas (TCFG).

No data indicate if the stratigraphic equivalent of the Thomson Sandstone, the Kemik Sandstone, exists in the rest of the 1002 Area, as no wells have been drilled outside of the confidential KIC #1 well. If it does exist, it is most likely to be encountered at depths ranging from 13,000 to 16,000 feet and will likely be gas or gas/condensate.

Figure 7-10 Map of the Point Thomson Field and Possible Extension into the 1002 Area



This page intentionally left blank.

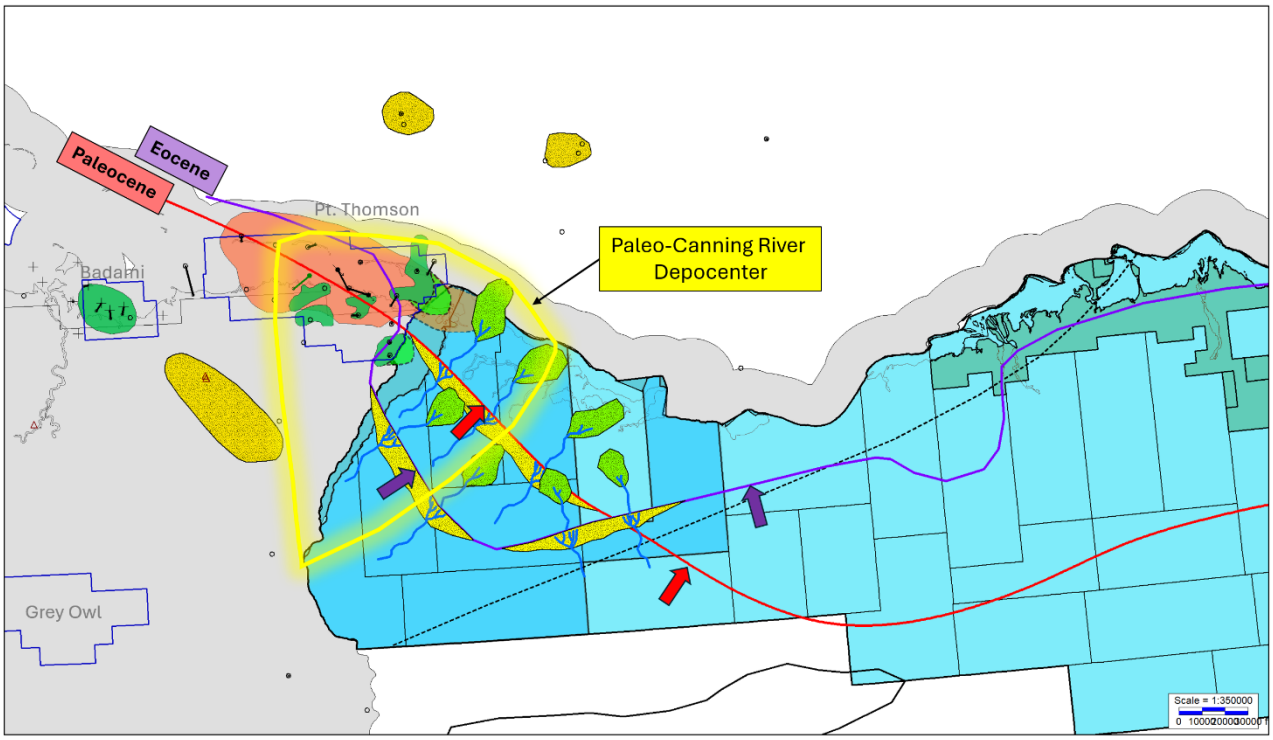
8.0 CONCLUSIONS AND RECOMMENDATIONS

The western portion of the ANWR 1002 Area is the most prospective unexplored onshore area in Alaska and in North America. Three different play types have been identified in this area (in order of highest potential to least): the Topset play, Turbidite play, and the Thomson-Kemik play (Figure 8-1). The western portion of the ANWR 1002 Area is our focus area due to its location within the undeformed area, proximity to established infrastructure to the west, and the presence of similar discoveries near the 1002 Area's western boundary, which provide high confidence through well control. The focus area has an estimated recoverable volume of approximately 4 to 6 BBO, with about 3 to 5 BBO in the Topset play and 1 BBO in the Turbidite play. The Thomson-Kemik play is unknown because it is difficult to detect using seismic data and is likely deep and gas-prone.

Overall, the paleo-Canning River depocenter area will have the best reservoir development for the Topset and Turbidite plays. The Thomson Sandstone most likely extends into the very northwest part of the 1002 Area. 3-D survey data is critical for detecting and delineating both the Topset and Turbidite prospects. The Pikka and Willow Topset discoveries, as well as the nearby Turbidite discoveries within and around the Point Thomson field, were identified and delineated using 3-D seismic data. A more detailed discussion about the 3-D survey is discussed in the confidential addendum of this report.

The northwest area of the 1002 Area is highly prospective and considered low risk due to the proximity to the Thompson Field, well control near the 1002 boundary, and existing infrastructure at Point Thomson, all of which will lower development costs. Development within the 1002 Area also has the potential to create long-term sustainable jobs and generate approximately $3.5 billion to various government agencies, including the North Slope Borough, the State of Alaska, and the U.S. government, as well as for Alaska Native communities.

Figure 8-1 Map Showing All Three Play Types



Note: Map shows all three play types, nearby discoveries, and the paleo-Canning River depocenter.

9.0 REFERENCES

Alaska Industrial Development and Export Authority (AIDEA). 2024. "Section 1002 Area." Accessed September 26, 2024. https://www.aidea.org/Programs/Arctic-Infrastructure-Development-Fund-AIDF/1002-Area.

APA Corporation. 2025a. "APA Corporation and partners Lagniappe Alaska and Santos announce significant oil discovery in Alaska's North Slope at Sockeye-2 exploration well; partners proceeding with further evaluation and testing." Press Release. Accessed August 22, 2025. https://investor.apacorp.com/news-releases/news-release-details/apa-corporation-and-partners-lagniappe-alaska-and-oil-search.

APA Corporation. 2025b. "APA Corporation and partners Lagniappe Alaska and Santos announce successful flow test in Alaska's North Slope at Sockeye-2 exploration well." Press Release. Accessed August 22, 2025. https://investor.apacorp.com/news-releases/news-release-details/apa-corporation-and-partners-lagniappe-alaska-and-santos.

Bureau of Land Management (BLM). 2024. "Coastal Plain of the Arctic National Wildlife Refuge." Accessed September 26, 2024. https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/about/alaska/coastal-plain-arctic-national-wildlife-refuge.

Congressional Research Service. 2025. *Arctic National Wildlife Refuge: Status of Oil and Gas Program.* CRS Report IF12006. Accessed August 20, 2025. https://www.congress.gov/crs-product/IF12006?q=%7B%22search%22%3A%22IF12006%22%7D&s=3&r=1.

DeMarban, A. 2025. "Curtain closes on another Arctic refuge lease sale after feds receive zero bids." Anchorage Daily News. Accessed August 20, 2025. https://www.adn.com/business-economy/energy/2025/01/08/feds-receives-no-bids-for-arctic-refuge-oil-and-gas-lease-sale/.

Exploration Geosciences LTD. 1999. Report on the North Slope (Industry Area) and Arctic National Wildlife Refuge

Gregersen, L. S., and G. A. Brown. 2021. "Map and Database of Exploration Drilling Targets Categorized by Play Type, North Slope and Offshore Arctic Alaska." Alaska Division of Geological & Geophysical Surveys Miscellaneous Publication 167. 15 p., 4 sheets, scale 1:725,000. https://doi.org/10.14509/30579.

Houseknecht, D. W. 2019. "Geological and Petroleum Systems Framework of the ANWR Coastal Plain." Search and Discovery Article #30645. Oral presentation at AAPG Annual Convention & Exhibition, San Antonio, TX, May 19-22. DOI: 10.1306/30645Houseknecht2019.

Jones, V. L. 2023. "Sedimentary Processes and Depositional Model for the Badami Reservoir, North Slope, Alaska." PhD dissertation. https://www.proquest.com/openview/f5fc04c871d89a6964d29dbf4a0500a5/1?pq-origsite=gscholar&cbl=18750&diss=y.

Magoon, L. B., et al. 1999. "Evaluation of Hydrocarbon Charge and Timing Using the Petroleum System," in The Oil and Gas Resource Potential of the 1002 Area, Arctic National Wildlife Refuge, Alaska, U.S. Geological Survey, Open-File Report 98-34.

National Archive of Marine Seismic Surveys (NAMSS). 2016. A USGS data website of marine seismic reflection data within the U.S. Exclusive Economic Zone (EEZ): U.S. Geological Survey Data Release, doi: 10.5066/F7930R7P.

RDC 44th Annual Membership Luncheon. 2019. “Oil Search & Alaska: Forging a path forward in the Nanushuk.”

Schepp, K. 2024. "Arctic National Wildlife Refuge Location." Accessed September 26, 2024. https://arcticnationalwildliferefuge.weebly.com/.

State of Alaska. 2013. "The State of Alaska's ANILCA Section 1002(e) Exploration Plan and Special Use Permit Application and Supporting Materials." Department of Natural Resources. Accessed March 11, 2024. https://catalog.northslopescience.org/tr/dataset/2602.

U.S. Department of the Interior (DOI). 1987. *Arctic National Wildlife Refuge, Alaska, Coastal Plain Resource Assessment: Report and Recommendation to the Congress of the United States and Final Legislative Environmental Impact Statement.* Prepared by the U.S. Fish and Wildlife Service, in collaboration with the U.S. Geological Survey and the Bureau of Land Management. Accessed March 11, 2024. Accessed March 11, 2024. https://pubs.usgs.gov/fedgov/70039559/report.pdf.

U.S. Geological Survey (USGS). 1987. *Petroleum Geology of the Northern Part of the Arctic National Wildlife Refuge, Northeastern Alaska,* U.S. Geological Survey Bulletin 1778. https://doi.org/10.3133/b1778.

U.S. Geological Survey (USGS). 1998. *The Oil and Gas Resource Potential for the Arctic National Wildlife Refuge 1002 Area, Alaska: U.S. Geological Survey, Open-File Report 98-34, Including Economic Analysis.* Accessed March 11, 2024. https://pubs.usgs.gov/fs/fs-0028-01/fs-0028-01.htm.

U.S. Geological Survey (USGS). 2005. *Undiscovered Oil Resources in the Federal Portion of the 1002 Area of the Arctic National Wildlife Refuge: An Economic Update*, U.S. Geological Survey, Open-File Report 2005-1217. https://pubs.usgs.gov/of/2005/1276/2005-1276_v1-1.pdf.

Electronic Distribution

Client: Alaska Industrial Development and Export Authority
813 W Northern Lights Blvd.
Anchorage, AK 99503
Attn: Taryn Perez and Jeffrey San Juan

Project Manager: Veronica Jones

Project File: 18168.01-24-249

QUALITY CONTROL REVIEWER

Amanda Henry

Amanda Henry, JD
Director of Business Operations and Regulatory Strategy

Technical Editor: Lori Jo Oswald

This page intentionally left blank.