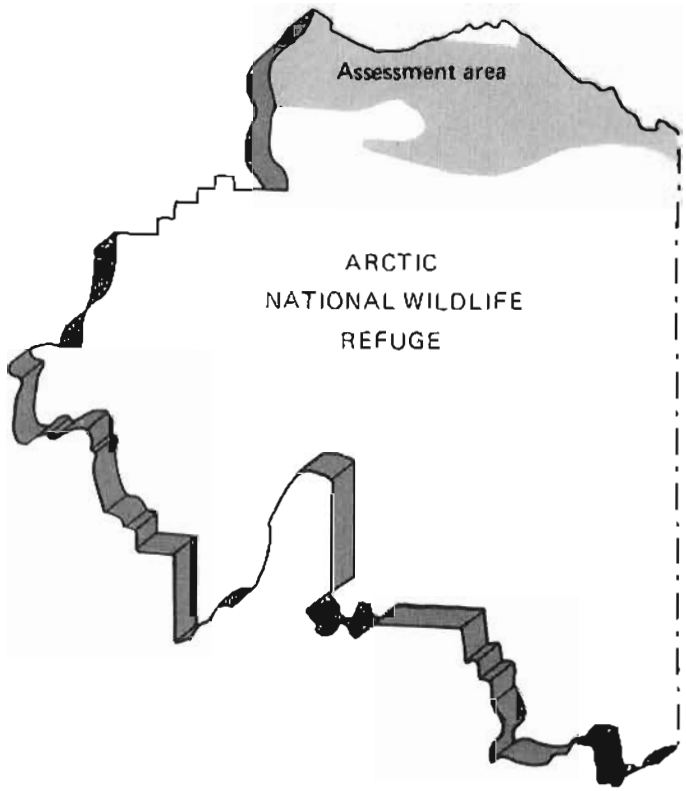
RESOURCE APPRAISAL SIMULATION FOR PETROLEUM IN THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

Compiled by J.J. Hansen and R.W. Kornbrath



PROFESSIONAL REPORT 90

Published by

State of Alaska
Department of Natural Resources
Division of Geological & Geophysical Surveys

1986

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Professional Report 90

Fairbanks, Alaska
1986

STATE OF ALASKA

Bill Sheffield, *Governor*

Esther C. Wunnicke, *Commissioner,*
Department of Natural Resources

Ross G. Schaff, *Director and State Geologist*

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FOREWORD

In 1985, the Secretary of the U.S. Department of the Interior and the Commissioner of the Alaska Department of Natural Resources signed an agreement to share geologic and geophysical data collected from the Arctic National Wildlife Refuge (ANWR). Scientists of the Department of Natural Resources analyzed these data and prepared estimates of the oil-and-gas potential of the coastal plain of ANWR, as stipulated in the agreement. These estimates are reported in this document.

Ross G. Schaff
Director and State Geologist

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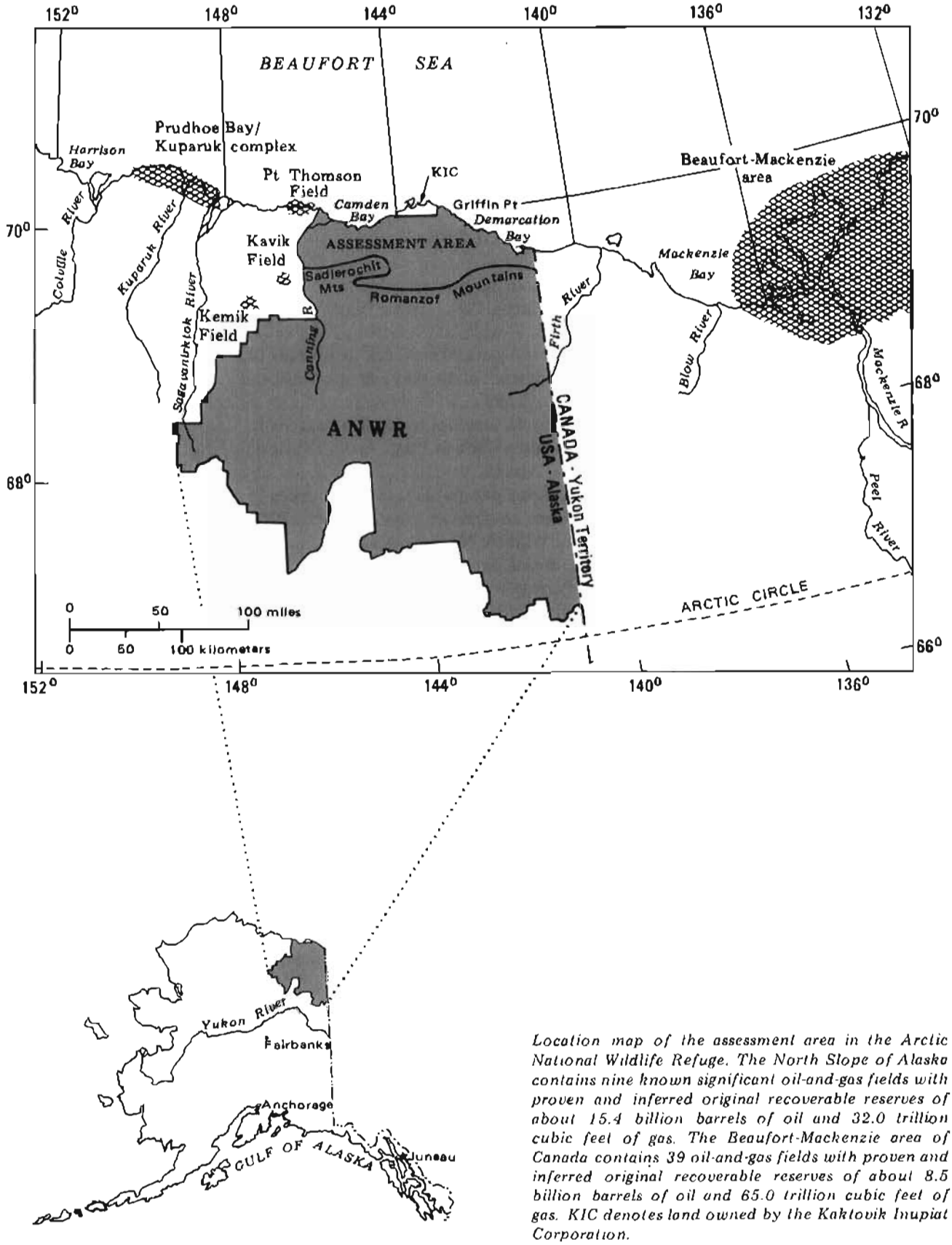

Location map of the assessment area in the Arctic National Wildlife Refuge. The North Slope of Alaska contains nine known significant oil-and-gas fields with proven and inferred original recoverable reserves of about 15.4 billion barrels of oil and 32.0 trillion cubic feet of gas. The Beaufort-Mackenzie area of Canada contains 39 oil-and-gas fields with proven and inferred original recoverable reserves of about 8.5 billion barrels of oil and 65.0 trillion cubic feet of gas. KIC denotes land owned by the Kaktovik Inupiat Corporation.

RESOURCE APPRAISAL SIMULATION FOR PETROLEUM IN THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

Compiled by J.J. Hansen[1] and R.W. Kornbrath[1]

INTRODUCTION

This report presents the results of the State's preliminary appraisal of the potential for undiscovered petroleum resources on the coastal plain of the Arctic National Wildlife Refuge (ANWR), Alaska. The assessment area is located north of the Sadlerochit and Romanzof Mountains between the Canning River and the Canadian border. The study area does not include that portion of the coastal plain from eastern Camden Bay to Griffin Point (owned by the Kaktovik Inupiat Corporation[2]) or state-submerged lands offshore from ANWR.

Members of the appraisal panel from the Alaska Department of Natural Resources include C. Ariey, J.E. Decker, J.J. Hansen, R.W. Kornbrath, D.L. Krouskop, C.G. Mull, G.H. Pessel, M.S. Robinson, T.N. Smith, and S.M. Weum. B.H. White and R. Anderson (U.S. Bureau of Mines) and E.L. Phillips (Alaska Department of Natural Resources) assisted in the computer analysis of the data.

A resource appraisal of ANWR was completed in 1980 by the U.S. Geological Survey. At that time, the available data consisted of limited gravity and aeromagnetic surveys augmented by some geologic mapping. Since then, additional geologic studies, two proprietary gravity surveys, and two seismic surveys have been conducted. Interpretation of this new information has resulted in revised hypotheses about the geologic evolution of the coastal plain.

The methodology used to assess the resource potential of the coastal plain of ANWR is the Resource Appraisal Simulation for Petroleum (RASP), which was developed by the U.S. Department of Interior Office of Minerals Policy and Research Analysis. RASP is a simulation (or modeling) procedure that geoscientists use to assess the undiscovered oil-and-gas potential of frontier basins. The basic unit of analysis is the geologic play, which is defined as a stratigraphic unit in a relatively homogeneous geologic setting. A basin will normally consist of one or more plays of interest; the geologic plays for this appraisal are presented in figures 1 through 7 (app.).

Resource estimates are presented as probability distributions that reflect the uncertainty inherent in appraising undiscovered resources. The resources estimated to exist in each play are combined to produce an estimate of the total 'undiscovered, conditional resources in place' as barrels of oil, cubic feet of gas, and barrels of oil equivalent for the study area. In addition, a probability distribution of the deposit size is generated for each play and for the total resources in place. Deposit size is important for economic considerations; for instance, less than 350 million barrels of recoverable oil in ANWR may not be commercially viable. A more detailed discussion of the RASP methodology is included on page 3.

ASSESSMENT RESULTS

The results of the petroleum-resource assessment are summarized in tables 1 through 4. Probability distributions for total oil, total gas, total barrels of oil equivalent, and oil-and-gas deposit sizes are presented at various fractiles that range from 0.99 to 0.01. The distribution values may be interpreted as follows. The 0.95 fractile means that there is a 95-percent chance that at least that amount of the associated resource is present. For oil, there is a 95-percent chance that ANWR contains at least 80 million barrels of oil. Similarly, there is a 1-percent chance that ANWR contains at least 45.78 billion barrels of oil. The 0.50 fractile is not the most likely case of occurrence. Rather, it is the median of the distribution and indicates a 50-percent chance that the quantity of resource present could be greater or less than its associated value.

The results in tables 1 and 2 show that in the range between the 95th and 5th fractiles, the resource potential of ANWR ranges from 0.08 to 26.52 billion barrels of oil (BBO) and from 0.71 to 43.62 trillion

[1]Alaska Division of Geological and Geophysical Surveys, P.O. Box 7028, Anchorage, Alaska 99510.

[2]An additional assessment that includes the KIC lands was performed by the Alaska Department of Natural Resources.

Table 1. *Total oil, ANWR petroleum-resource assessment.*

Fractile	Billion barrels
0.99	0.00
0.98	0.00
0.97	0.01
0.96	0.04
0.95	0.08
0.90	0.33
0.75	1.28
0.50	3.77
0.25	9.18
0.10	17.94
0.05	26.52
0.04	29.68
0.03	34.14
0.02	38.94
0.01	45.78

Minimum simulated oil	Maximum simulated oil
0.00	81.77
Average oil	**Standard deviation**
7.22	9.66

Table 2. *Total gas, ANWR petroleum-resource assessment.*

Fractile	Trillion ft^3
0.99	0.08
0.98	0.26
0.97	0.40
0.96	0.56
0.95	0.71
0.90	1.42
0.75	3.74
0.50	8.64
0.25	17.77
0.10	31.94
0.05	43.62
0.04	46.65
0.03	52.67
0.02	62.26
0.01	76.24

Minimum simulated gas	Maximum simulated gas
0.00	159.92
Average gas	**Standard deviation**
13.69	15.76

Table 3. *Total deposit size, ANWR petroleum-resource assessment.*

Fractile	Conditional, 100% oil (million barrels)	Conditional, 100% gas (billion ft^3)
0.99	3.202	5.797
0.98	6.115	10.252
0.97	8.766	14.854
0.96	11.154	19.368
0.95	14.556	23.382
0.90	30.865	45.115
0.75	102.155	143.645
0.50	354.131	509.171
0.25	1173.606	1721.490
0.10	3440.368	4846.398
0.05	6277.965	8912.465
0.04	7313.133	10861.937
0.03	8898.691	13492.098
0.02	11821.965	18052.875
0.01	18272.949	26867.359
Minimum simulated deposit	0.10	0.40
Average	1459.56	2143.70
Maximum simulated deposit	76941.38	125833.06
Standard deviation	3762.19	5768.84

Table 4. *Total resources, ANWR petroleum-resource assessment. (barrels of oil equivalent, BOE)*

Fractile	Billion BOE
0.99	0.05
0.98	0.17
0.97	0.25
0.96	0.35
0.95	0.47
0.90	0.96
0.75	2.54
0.50	6.05
0.25	12.42
0.10	22.50
0.05	31.54
0.04	35.56
0.03	40.15
0.02	44.75
0.01	53.01

Minimum simulated BOE	Maximum simulated BOE
0.00	89.93
Average BOE	**Standard deviation**
9.64	11.06

cubic feet of gas (TCFG) in place, with an average value of 7.22 BBO and 13.69 TCFG. The median value (the 50th fractile) is 3.77 BBO and 8.64 TCFG (tables 1 and 2).

The resource distributions are strongly skewed toward the low-probability, high-resource values, as indicated by the difference between the average and median values (tables 1 and 2). This indicates that while only small quantities of resources are assured, there is a small chance that very large quantities of resources exist in ANWR.

Deposit-size estimates are equally important. For oil, the potential deposit sizes at the 1-percent confidence level range up to 18.27 BBO in place, with an average value of 1.46 BBO and a median value of 0.35 BBO. For gas, the potential deposit sizes at the 1-percent confidence level range up to 26.87 TCFG in place, with an average value of 2.14 TCFG and a median value of 0.51 TCFG (table 3).

In summary, the results of this evaluation indicate that the ANWR coastal plain may contain large petroleum deposits. On the basis of current data, large quantities of resources and large individual deposit sizes may occur within the coastal plain of ANWR. There is a 1-percent chance that the requisite parameters of source rock, timing, migration, reservoir rock, and trapping mechanisms have combined to generate up to 45.78 BBO and 76.24 TCFG in place in ANWR (tables 1 and 2). Assuming a recovery factor of 35 percent for oil, up to 16 billion barrels of recoverable oil may be present. This compares favorably with the original recoverable oil reserves of about 10 billion barrels in the Prudhoe Bay field.

GEOLOGIC PLAYS

The geologic play is the basic unit of analysis for resource assessment using the RASP methodology. Reservoir-quality rocks, known production, and trapping mechanisms are the most important parameters used to define specific plays in this assessment. Parameters such as thermal maturity, source-rock distribution, and timing are also requisite for a successful play. Specific plays used to assess the resource potential of ANWR include Kekiktuk (fig. 1), Lisburne North and South (figs. 2 and 3), Permian-Triassic Clastics North and South (figs. 4 and 5), Kemik-Thomson (fig. 6), and Post-Albian Clastics (fig. 7). A stratigraphic column and oil-and-gas summary for these plays are shown in figure 8 (app.).

The sandstone, conglomerate, and carbonate lithologies of these plays have produced large quantities of oil and gas on the North Slope and in the Mackenzie Delta area of Canada. The combination of generation and migration of hydrocarbons from source shales and timing of trap formation has produced large fields. On the basis of surface studies and geologic modeling, similar favorable conditions may be present in the subsurface of ANWR.

Geologic field studies conducted by DGGS indicate the existence of complex relationships between various rock groups that comprise the geologic plays in the subsurface of the ANWR coastal plain. Simple structural closures, thrust-fault repetitions of rock units, and complex folds could provide mechanisms to structurally trap hydrocarbons. Truncation of rock units and facies changes could also result in stratigraphic traps.

Plays of the Kekiktuk, Kemik-Thomson, and Post-Albian Clastics (figs. 1, 6, and 7) are broad in scope and are anticipated to be present throughout the study area. However, based on possible truncation of the rock units by a major unconformity, plays of the Lisburne North and Permian-Triassic Clastics North (figs. 2 and 4) are less likely to occur in the study area.

PROCEDURES FOR OIL-AND-GAS RESOURCE APPRAISALS

The procedure for the Resource Appraisal Simulation for Petroleum (RASP) incorporates a 'play' approach to petroleum-resource assessment. The methodology focuses on the concept of a geologic play as the basic unit of geologic analysis. The play is defined as a stratigraphic unit in a relatively homogeneous geologic setting.

A play approach to resource assessment of large basins or regions was chosen for the following reasons:

- The approach provides a direct assessment of the geologic characteristics—and their uncertainty—for the area of interest.
- The level of geologic detail provided by the play approach is sufficient to support a meaningful analysis.
- The approach does not require explicit identification and substantial detail for individual prospects.
- The approach recognizes regional trends within a play that enable prospects to be geologically correlated.

In essence, the play approach divides the traditional dry-hole risk factor into two components. The first component is the risk that is common to all prospects in the play because they share a common potential for source material, migration, timing, and reservoir rock. The second component is the risk that an individual prospect may have a geologic flaw specific to it and independent of other prospects in the play. Finally, the approach does not require actual discoveries in a play for assessment purposes. Judgments may be based on existing data and can explicitly reflect the uncertainty in those data.

Geoscientists familiar with the geology are asked to make three sets of probability judgments for each play.

The first set of judgments concerns the individual probabilities that each of four regional geologic characteristics common to the play area is favorable for the existence of petroleum accumulations. These regional characteristics are the existence of a petroleum source, favorable timing, potential migration paths, and reservoir rock. The product of these four probabilities is the marginal-play probability, that is, the joint probability that all regional geologic characteristics necessary for the accumulation of petroleum in the play area are simultaneously favorable. The existence of each geologic characteristic is necessary, but not sufficient to forecast the existence of oil or gas deposits in the play. If oil or gas have been found in a particular play, the marginal-play probability is 1.0. If none have been discovered in a play, additional probability judgments are necessary to determine the existence of hydrocarbon deposits.

The number of potentially drillable prospects in the play area, reservoir lithology (sandstone or carbonate), and petroleum mix (proportion of deposits within the play that are anticipated to be oil rather than nonassociated gas) are also needed to evaluate each play. The RASP program assumes that petroleum accumulations exist only as gas deposits below 15,000 feet.

The second set of judgments is a set of probabilities that concerns the presence of three geologic characteristics that are common to the individual prospects within each play:

- Trapping mechanism. This defines the method that restricts hydrocarbon migration, which can be related to structure or stratigraphy, or both. A trap must have an areal extent of at least 600 acres with vertical closure of at least 5 feet.
- Effective porosity. The interconnected void space that may hold hydrocarbons must be equal to or greater than 3 percent.
- Hydrocarbon accumulation. Oil and gas must exist in at least 1 percent of a trap. This expresses the favorable relationships of source rock to reservoir rock and timing of hydrocarbon generation to trap formation.

The probability judgment is conditional on the existence of these three geologic characteristics. The product of the three attribute probabilities is the conditional-deposit probability, that is, the probability that a particular prospect is an actual accumulation of oil or gas, given that all play attributes are favorable. The familiar dry-hole risk factor is equal to one minus the product of the marginal-play probability and the conditional-deposit probability.

The third set of probability judgments involves the geologic parameters of the reservoir that determine the size of the potential deposits. These reservoir characteristics are area of closure, reservoir thickness, effective porosity, trap fill, reservoir depth, reservoir lithology, and hydrocarbon mix. Jointly, these parameters determine the potential reservoir volume for a deposit.

These three basic sets of judgments—geologic characteristics common to the play area, geologic characteristics common to the individual prospects within each play, and geologic parameters that determine the size of the potential deposits—are made for each identified play and comprise the basic geologic data necessary for a resource appraisal.

The probability distribution for each characteristic is randomly sampled to simulate one possible state of geologic nature. For example, the probability distribution for the number of potentially drillable prospects is sampled to determine the number of prospects that will be simulated for the play. The marginal-play probability is then sampled to determine whether the play will be simulated as unproductive or potentially productive. For each simulated prospect in a productive play, the conditional-deposit probability is sampled to determine whether that prospect will be treated as dry or as a deposit. The petroleum-mix probability is sampled for each deposit to simulate whether it contains oil or gas, but not both. All prospects in an unproductive play are automatically simulated to be dry. Each reservoir-parameter distribution is sampled for each deposit to simulate its volume and reservoir characteristics. This sampling procedure is repeated 3,000 times in a typical Monte Carlo method, and the results are combined to develop probability distributions for oil, gas, barrels of oil equivalent in place, and deposit size.

APPENDIX

Areal distribution, input parameters, and resources in place for geologic plays

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	0.00	0.00
0.25	0.00	0.00	0.00
0.10	6.56	131.66	57.61
0.05	105.72	377.90	196.04
0.01	634.34	1591.72	860.35

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	0.536	2.376
0.95	1.809	10.096
0.90	4.322	20.976
0.75	21.118	48.852
0.50	62.437	152.273
0.25	222.442	432.578
0.10	559.760	1025.895
0.05	891.911	1686.935
0.01	3558.948	4129.762

Attribute			Probability that attribute is favorable or present
Play attributes	Hydrocarbon sources		1
	Timing		1
	Migration		1
	Potential reservoir facies		1
	Marginal-play probability		1
Prospect attributes	Trapping mechanism		0.25
	Effective porosity (>3%)		0.3
	Hydrocarbon accumulation		0.3
	Conditional-deposit probability		0.0225
Hydrocarbon volume parameters	Reservoir lithology	Sand	1
		Carbonate	0
	Hydrocarbon mix	Gas	0.4
		Oil	0.6

Attribute \ Fractiles	Probability of equal to or greater than						
	1.00	0.95	0.75	0.50	0.25	0.05	0
Area of closure ($x10^3$ acres)	0.6	1	3	5	15	25	100
Reservoir thickness/ vertical closure (ft)	5	25	60	75	100	200	1000
Effective porosity (%)	3	4	6	8	12	16	20
Trap fill (%)	1	6	30	60	80	96	100
Reservoir depth ($x10^3$ ft)	5	8	10	12	15	20	30
Number of drillable prospects (a play characteristic)	1	2	4	7	15	25	50

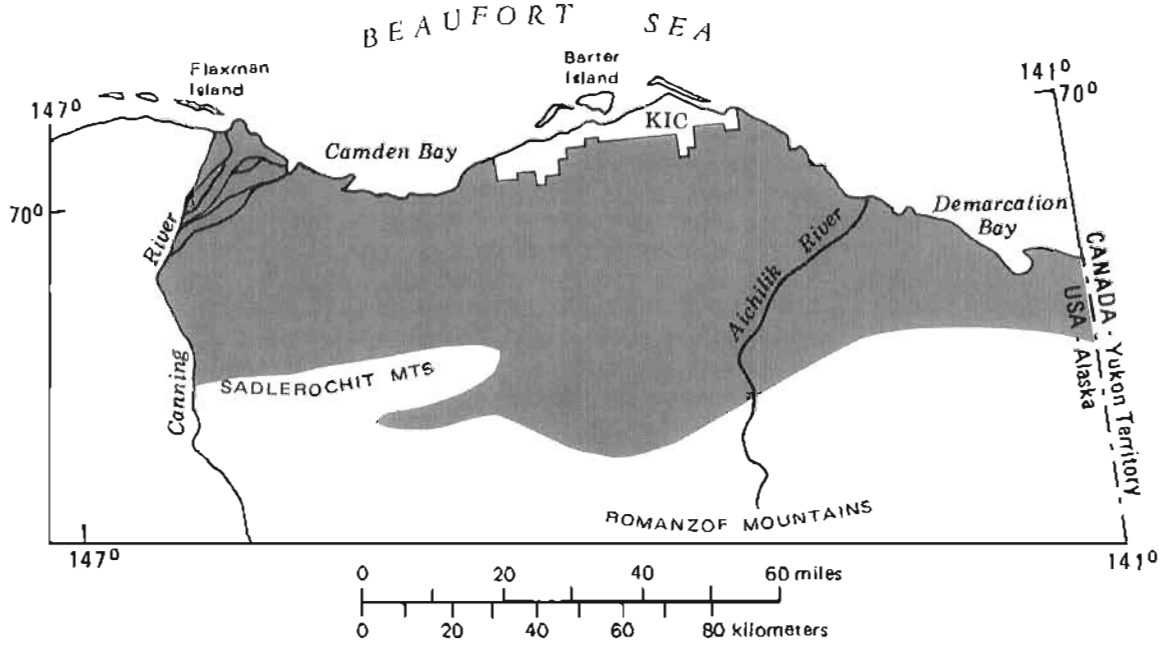

Figure 1. Areal distribution, input parameters, and resources in place for the Kekiktuk Play, Arctic National Wildlife Refuge, Alaska.

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	0.00	0.00
0.25	0.00	0.00	0.00
0.10	0.00	0.00	0.00
0.05	0.00	75.28	48.54
0.01	234.23	670.64	325.42

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	3.720	15.887
0.95	9.020	25.298
0.90	17.780	73.341
0.75	42.483	146.806
0.50	95.310	292.110
0.25	234.471	617.343
0.10	461.101	1723.089
0.05	536.209	1832.462
0.01	3207.997	4330.336

	Attribute		Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		0.8						
	Potential reservoir facies		0.5						
	Marginal-play probability		0.4						
Prospect attributes	Trapping mechanism		0.3						
	Effective porosity (>3%)		0.1						
	Hydrocarbon accumulation		0.4						
	Conditional-deposit probability		0.012						
Hydrocarbon-volume parameters	Reservoir lithology	Sand	0						
		Carbonate	1						
	Hydrocarbon mix	Gas	0.4						
		Oil	0.6						
	Attribute \ Fractiles		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($\times 10^3$ acres)		0.6	3	10	12	15	30	100
	Reservoir thickness/ vertical closure (ft)		5	50	125	200	350	500	750
	Effective porosity (%)		3	3	4	4	5	6	10
	Trap fill (%)		1	5	25	50	75	95	100
	Reservoir depth ($\times 10^3$ ft)		6	9	11	13	19	23	29
Number of drillable prospects (a play characteristic)			2	4	4	5	8	10	20

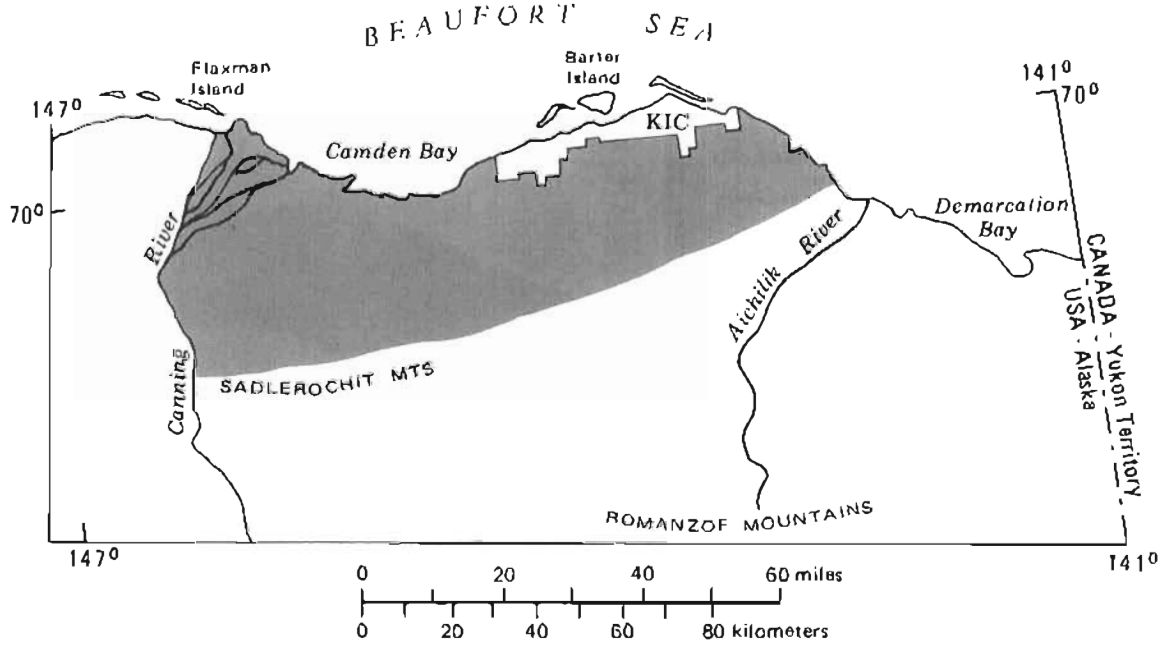

Figure 2. Areal distribution, input parameters, and resources in place for the Lisburne North Play, Arctic National Wildlife Refuge, Alaska.

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	0.00	0.00
0.25	0.00	0.00	0.00
0.10	0.00	13.85	10.04
0.05	64.03	170.30	129.34
0.01	624.02	1021.80	777.91

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	3.812	2.779
0.95	11.388	9.681
0.90	19.488	17.355
0.75	54.967	56.067
0.50	163.679	172.416
0.25	406.565	454.902
0.10	796.095	1280.341
0.05	1536.064	2064.430
0.01	2277.339	5454.289

Attribute			Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		1						
	Potential reservoir facies		1						
	Marginal-play probability		1						
Prospect attributes	Trapping mechanism		0.25						
	Effective porosity (>3%)		0.1						
	Hydrocarbon accumulation		0.4						
	Conditional-deposit probability		0.01						
Hydrocarbon volume parameters	Reservoir lithology	Sand	0						
		Carbonate	1						
	Hydrocarbon mix	Gas	0.4						
		Oil	0.6						
	Attribute \ Fractiles		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($\times 10^3$ acres)		0.6	1	3	5	10	30	100
	Reservoir thickness/ vertical closure (ft)		5	100	225	350	425	600	1200
	Effective porosity (%)		3	3	4	4	5	6	10
	Trap fill (%)		1	5	25	50	75	95	100
	Reservoir depth ($\times 10^3$ ft)		2	5	7	9	12	14	20
Number of drillable prospects (a play characteristic)			1	5	8	10	15	25	100

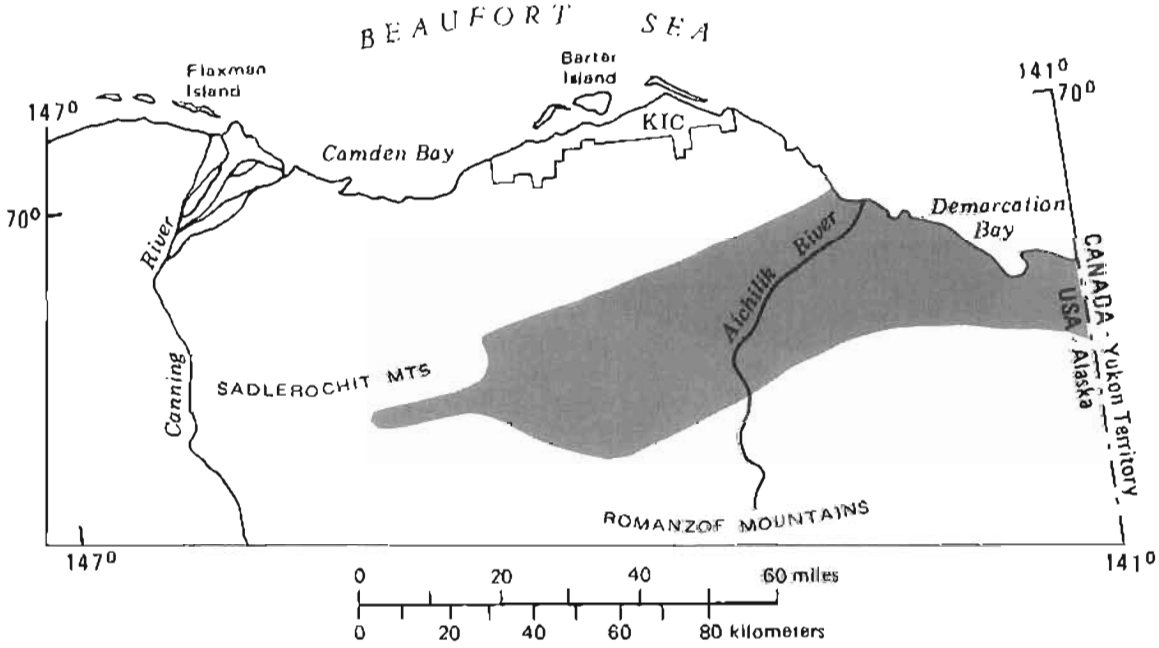

Figure 3. Areal distribution, input parameters, and resources in place for the Lisburne South Play, Arctic National Wildlife Refuge, Alaska.

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	0.00	0.00
0.25	0.00	689.02	292.14
0.10	948.85	2927.37	1339.20
0.05	1927.34	5123.80	2619.52
0.01	5981.70	11366.90	7005.12

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	11.112	15.476
0.95	41.465	53.727
0.90	70.171	148.026
0.75	174.012	417.946
0.50	538.918	1163.055
0.25	1323.921	2905.923
0.10	2925.320	5803.098
0.05	4333.508	7478.438
0.01	9932.547	14709.691

	Attribute		Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		1						
	Potential reservoir facies		0.5						
	Marginal-play probability		0.5						
Prospect attributes	Trapping mechanism		0.3						
	Effective porosity (>3%)		0.8						
	Hydrocarbon accumulation		0.4						
	Conditional-deposit probability		0.096						
Hydrocarbon-volume parameters	Reservoir lithology	Sand	1						
		Carbonate	0						
	Hydrocarbon mix	Gas	0.4						
		Oil	0.6						
	Fractiles / Attribute		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($\times 10^3$ acres)		0.6	3	10	12	15	30	100
	Reservoir thickness/ vertical closure (ft)		5	50	125	200	350	500	750
	Effective porosity (%)		3	7	13	15	18	23	30
	Trap fill (%)		1	5	25	50	75	95	100
	Reservoir depth ($\times 10^3$ ft)		5	8	10	12	18	22	28
Number of drillable prospects (a play characteristic)			2	4	4	5	8	10	20

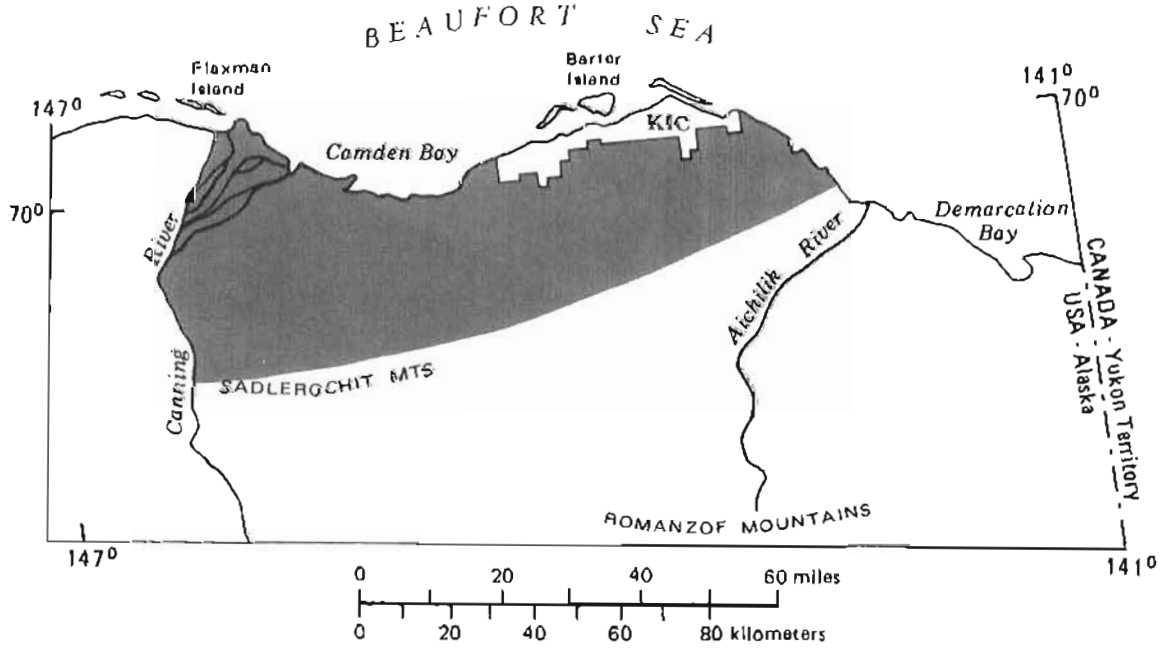

Figure 4. Areal distribution, input parameters, and resources in place for the Permian-Triassic Clastics North Play, Arctic National Wildlife Refuge, Alaska.

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	75.45	50.04
0.25	420.35	847.34	704.19
0.10	1923.32	2875.17	2514.74
0.05	3892.57	5362.30	4698.88
0.01	9535.30	13478.01	11477.75

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	5.751	6.613
0.95	19.493	23.007
0.90	41.787	53.101
0.75	141.340	156.387
0.50	424.294	545.440
0.25	1127.179	1495.480
0.10	2926.288	3769.860
0.05	4662.223	6053.766
0.01	9940.250	19075.750

	Attribute		Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		1						
	Potential reservoir facies		1						
	Marginal-play probability		1						
Prospect attributes	Trapping mechanism		0.25						
	Effective porosity (>3%)		0.8						
	Hydrocarbon accumulation		0.4						
	Conditional deposit probability		0.08						
Hydrocarbon-volume parameters	Reservoir lithology	Sand	1						
		Carbonate	0						
	Hydrocarbon mix	Gas	0.4						
		Oil	0.6						
	Fractiles / Attribute		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($\times 10^3$ acres)		0.6	1	3	5	10	30	100
	Reservoir thickness/ vertical closure (ft)		5	100	225	350	425	600	1000
	Effective porosity (%)		3	7	13	15	18	23	30
	Trap fill (%)		1	5	25	50	75	95	100
	Reservoir depth ($\times 10^3$ ft)		2	4	6	8	11	13	20
Number of drillable prospects (a play characteristic)			1	5	8	10	15	25	100

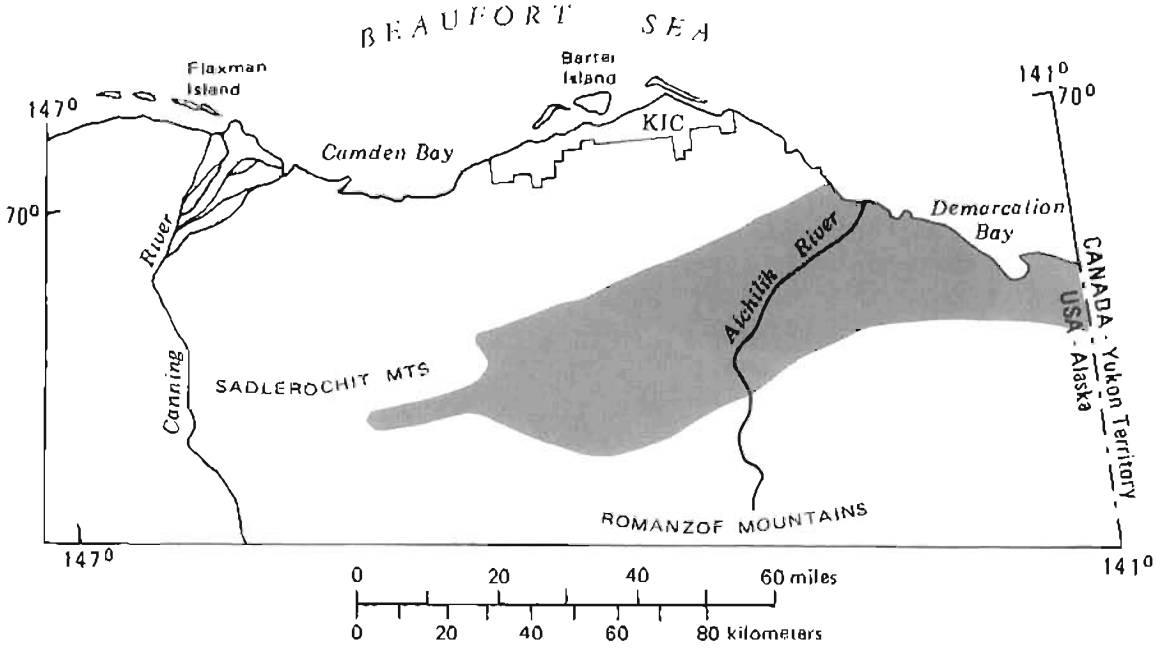

Figure 5 Areal distribution, input parameters, and resources in place for the Permian-Triassic Clastics South Play, Arctic National Wildlife Refuge, Alaska.

Gas fraction = 0.40
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	0.00	0.00
0.90	0.00	0.00	0.00
0.75	0.00	0.00	0.00
0.50	0.00	124.91	77.60
0.25	327.71	1075.43	654.49
0.10	1607.76	3468.63	2248.06
0.05	3122.80	5929.73	4097.80
0.01	7838.41	15008.58	9200.97

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	1.902	3.359
0.95	7.342	14.279
0.90	14.607	28.752
0.75	47.014	88.333
0.50	163.259	283.541
0.25	523.658	891.588
0.10	1602.893	2668.084
0.05	2813.698	4705.582
0.01	7445.875	14078.285

Attribute			Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		1						
	Potential reservoir facies		1						
	Marginal-play probability		1						
Prospect attributes	Trapping mechanism		0.25						
	Effective porosity (>3%)		0.9						
	Hydrocarbon accumulation		0.4						
	Conditional deposit probability		0.09						
Hydrocarbon-volume parameters	Reservoir lithology	Sand	1						
		Carbonate	0						
	Hydrocarbon mix	Gas	0.4						
		Oil	0.6						
	Fractiles / Attribute		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($x10^3$ acres)		0.6	2	3	5	15	40	100
	Reservoir thickness/ vertical closure (ft)		5	25	50	100	200	350	600
	Effective porosity (%)		3	5	10	15	20	25	30
	Trap fill (%)		1	6	30	60	80	96	100
	Reservoir depth ($x10^3$ ft)		2	5	8	10	15	20	25
Number of drillable prospects in play (characteristic)			2	3	6	12	25	50	100

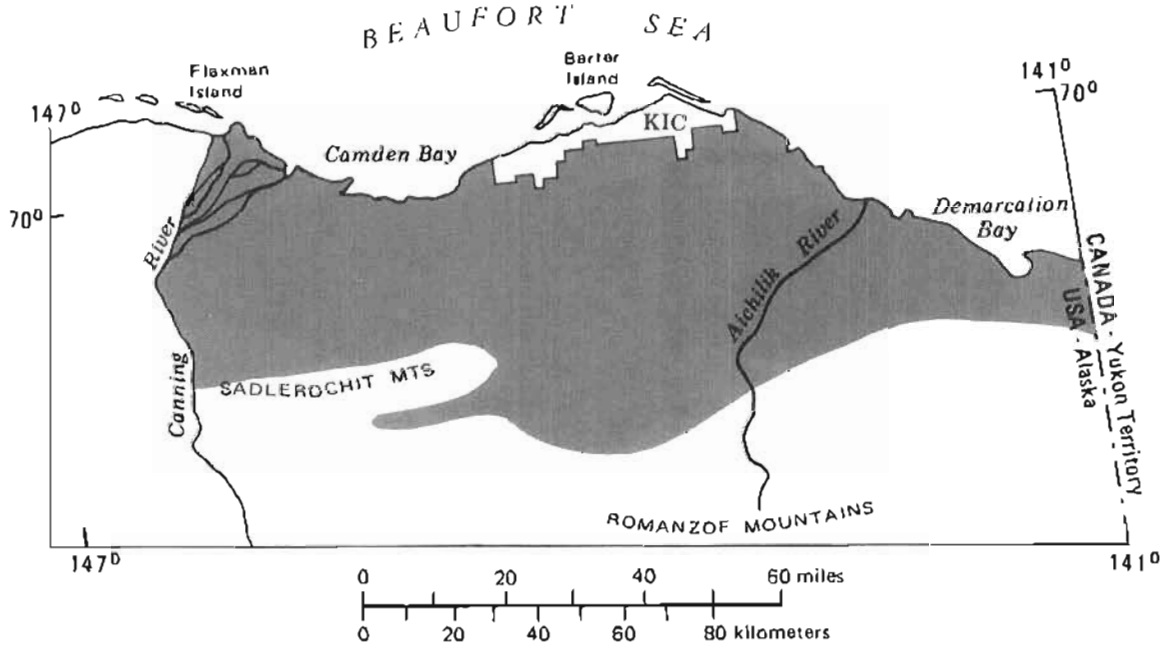

Figure 6. Areal distribution, input parameters, and resources in place for the Kemik-Thomson Play, Arctic National Wildlife Refuge, Alaska

Gas fraction = 0.50
Conditional resources in place

Fractile	Oil (million barrels)	Gas (billion ft^3)	BOE (million)
0.99	0.00	0.00	0.00
0.95	0.00	12.35	9.06
0.90	0.00	224.04	146.23
0.75	326.40	1498.50	1044.79
0.50	2097 78	5544 16	3785.89
0.25	6972.20	13623.56	9514.61
0.10	15625.20	28032.78	19546.79
0.05	24230 45	38904.07	29454.32
0.01	43382.48	74349.25	48926.22

Fractile	Deposit size Conditional, 100% oil (million barrels)	Deposit size Conditional, 100% gas (billion ft^3)
0.99	5.803	7.255
0.95	22.006	28.025
0.90	44.099	54.634
0.75	137.593	171.947
0.50	462.298	603.463
0.25	1542.427	2044.293
0.10	4489.004	5808.051
0.05	7927.445	10985.301
0.01	24037 582	32045.930

Attribute			Probability that attribute is favorable or present						
Play attributes	Hydrocarbon sources		1						
	Timing		1						
	Migration		1						
	Potential reservoir facies		1						
	Marginal-play probability		1						
Prospect attributes	Trapping mechanism		0.25						
	Effective porosity (>3%)		1						
	Hydrocarbon accumulation		0.5						
	Conditional-deposit probability		0.125						
Hydrocarbon-volume parameters	Reservoir lithology	Sand	1						
		Carbonate	0						
	Hydrocarbon mix	Gas	0.5						
		Oil	0.5						
	Fractiles / Attribute		Probability of equal to or greater than						
			1.00	0.95	0.75	0.50	0.25	0.05	0
	Area of closure ($\times 10^3$ acres)		0.6	1	2	4	12	30	75
	Reservoir thickness/ vertical closure (ft)		50	100	200	300	800	1200	2000
	Effective porosity (%)		3	5	10	15	19	23	30
	Trap fill (%)		1	6	30	60	80	96	100
	Reservoir depth ($\times 10^3$ ft)		2	3	4	6	9	12	20
Number of drillable prospects (a play characteristic)			5	10	25	40	70	100	200

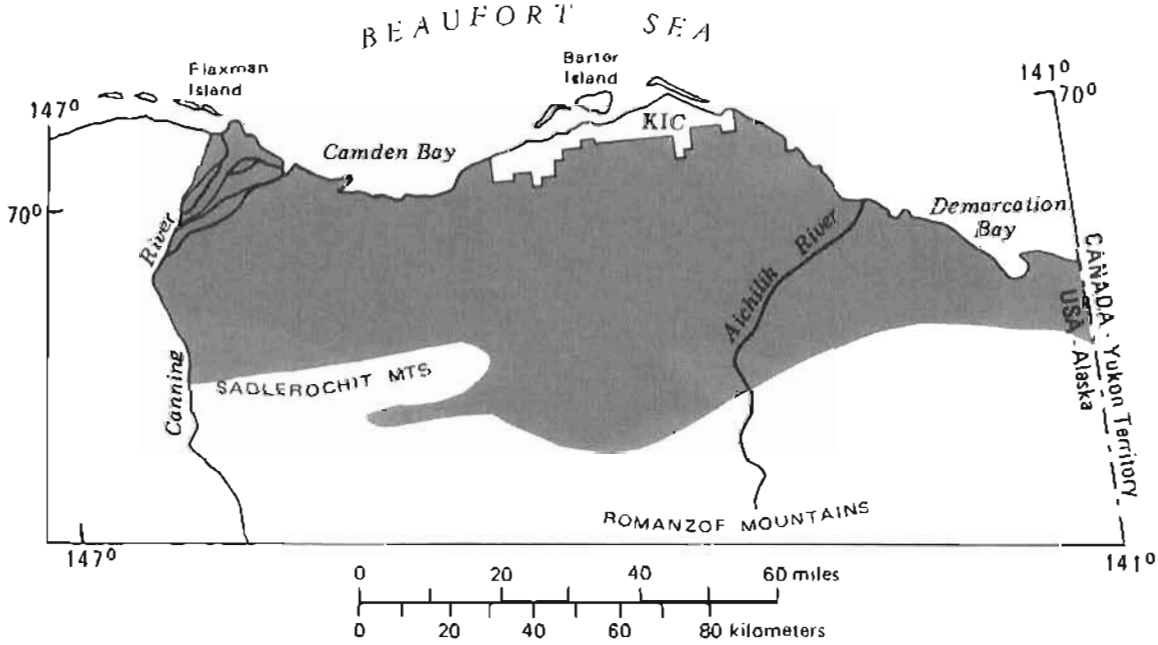

Figure 7. Areal distribution, input parameters, and resources in place for the Post-Albian Clastics Play, Arctic National Wildlife Refuge, Alaska.

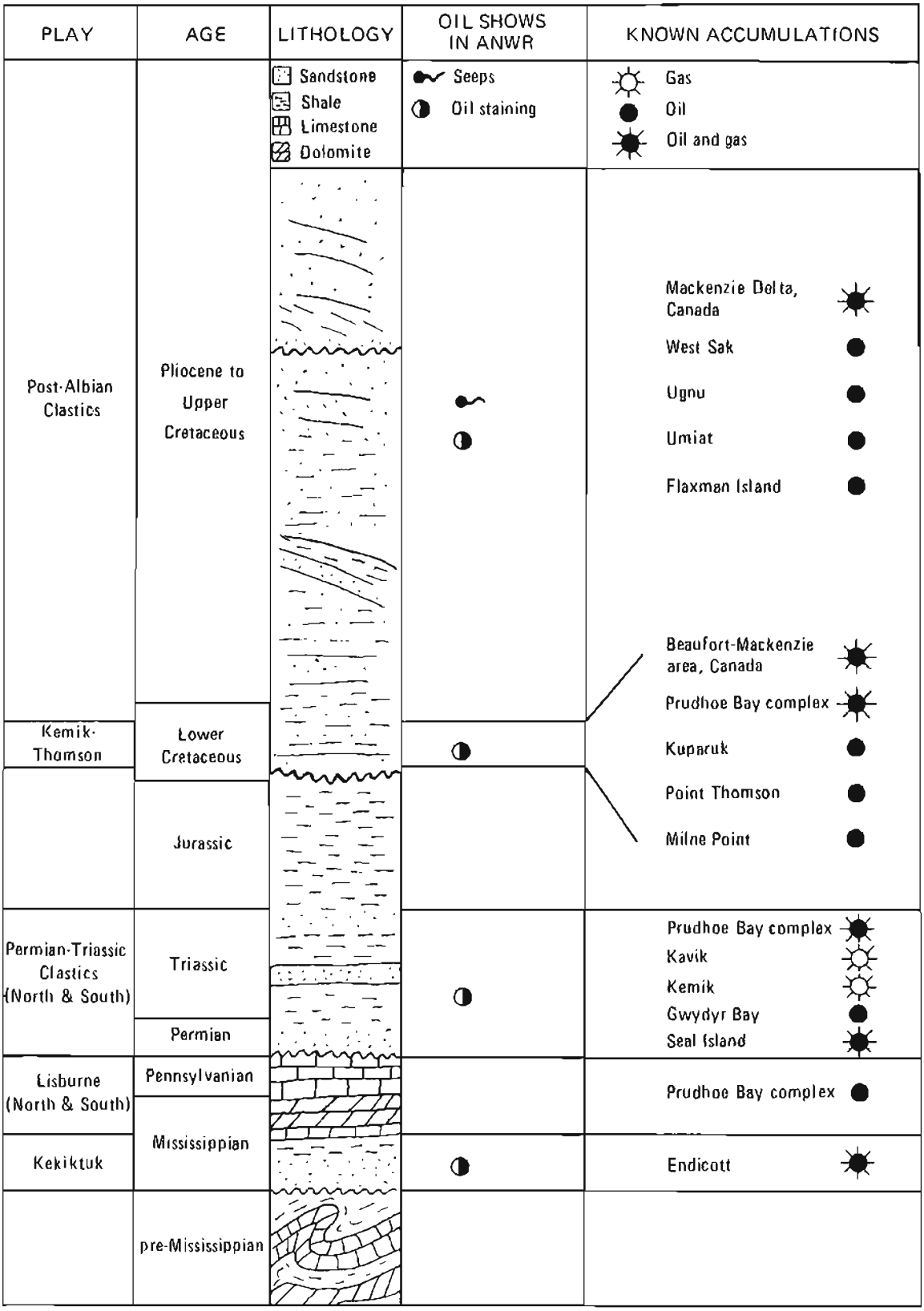

Figure 8. Stratigraphic column and oil-and-gas summary for plays in the Arctic National Wildlife Refuge, Alaska.