UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RESOURCE APPRAISAL OF UNDISCOVERED OIL AND GAS RESOURCES IN THE WILLIAM O. DOUGLAS ARCTIC WILDLIFE RANGE

By

R. F. Mast, R. H. McMullin, K. J. Bird, and W. P. Brosge

Open-file Report 80-916
July 1980

CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

The William O. Douglas Arctic Wildlife Range (WODAWR) covers about 9 million acres in the northeastern corner of Alaska. Questions regarding the future status of the Range, in particular, whether to allow mineral exploration and development, are the subject of much debate and the topic of legislation presently before Congress. The purpose of this report is to present details of the assessment of undiscovered in-place petroleum resources in the Wildlife Range. The assessment and specific use of the play method was requested by the Chairman of the U.S. Senate Committee on Energy and Natural Resources. The play method was used in the appraisal of the National Petroleum Reserve in Alaska (NPRA) and is the only assessment method amenable to the economic analysis used in the NPRA 105(b) study (U.S. Dept. of the Interior, 1979).

The Geologic Assessment and Resource Appraisal Review Committees appointed to accomplish this assessment met in Menlo Park between 13 May and 3 June 1980. The first of these, the Geological Assessment Committee, was comprised of 12 experts[1] on the geology of the Wildlife Range and adjacent onshore and offshore areas who met to review the geology, evaluation methods, and definition of terms to be use They then defined the plays and assessed the play parameters. Plays were established by major reservoir interval as in NPRA because it was more practical to assess reservoir properties and source rock relations of each reservoir unit. Seven experts in resource appraisal, plus 2 members from the

[1] Members of the Geological Assessment Committee were: W. Brosge (co-chairman), R. Detterman, A. Grantz, S. May, C. Mull, H. Reiser (Alaskan Geology Branch); K. Bird (co-chairman), L. Magoon, C. Molenaar (Branch of Oil and Gas Resources); I. Tailleur, (Office of National Petroleum Reserve in Alaska-ONPRA); I. Palmer (Conservation Division); and G. Pessel (State of Alaska).

Geologic Assessment Committee, met as the Resource Appraisal Review Committee[2] to conduct the assessment.

Representatives from the Office of Minerals Policy and Research Analysis (OMPRA)[3] were present at all meetings. They had developed the play program used here and previously in the NPRA assessment and economic analysis, and were available for consultation. They also provided on-the-spot computer results of the assessment.

The Wildlife Range, covering 13,900 square miles, consists mostly (73%) of mountainous terrane, the Brooks Range, with the remainder being a relatively narrow coastal plain adjacent to the Arctic Ocean. All of the petroleum potential is thought to be in the coastal plain portion and this was the area of assessment. This petroleum prospective area lies between the Prudhoe Bay area on the west and the Canadian Beaufort Sea-Mackenzie Delta area on the east (see figure 1). Although both of these areas contain petroleum reserves, they are quite different geologic provinces. The Wildlife Range exhibits characteristics of both provinces so that in spite of the relatively small size of the prospective area, one-tenth that of NPRA, confident projection of geologic trends is difficult because of pronounced lateral changes over relatively short distances. This factor complicates the assessment of the oil and gas resources.

---

2 Members of the Resource Appraisal Review Committee were: W. Brosge (Alaskan Geology Branch); K. Bird, G. Dolton, R. Mast, R. McMullin (chairman), R. Powers, E. Scott (Branch of Oil and Gas Resources); G. Gryc (ONPRA); and B. Miller (Director's Office).

3 Representatives from OMPRA included: R. Anderson, S. Miller, and L. White.

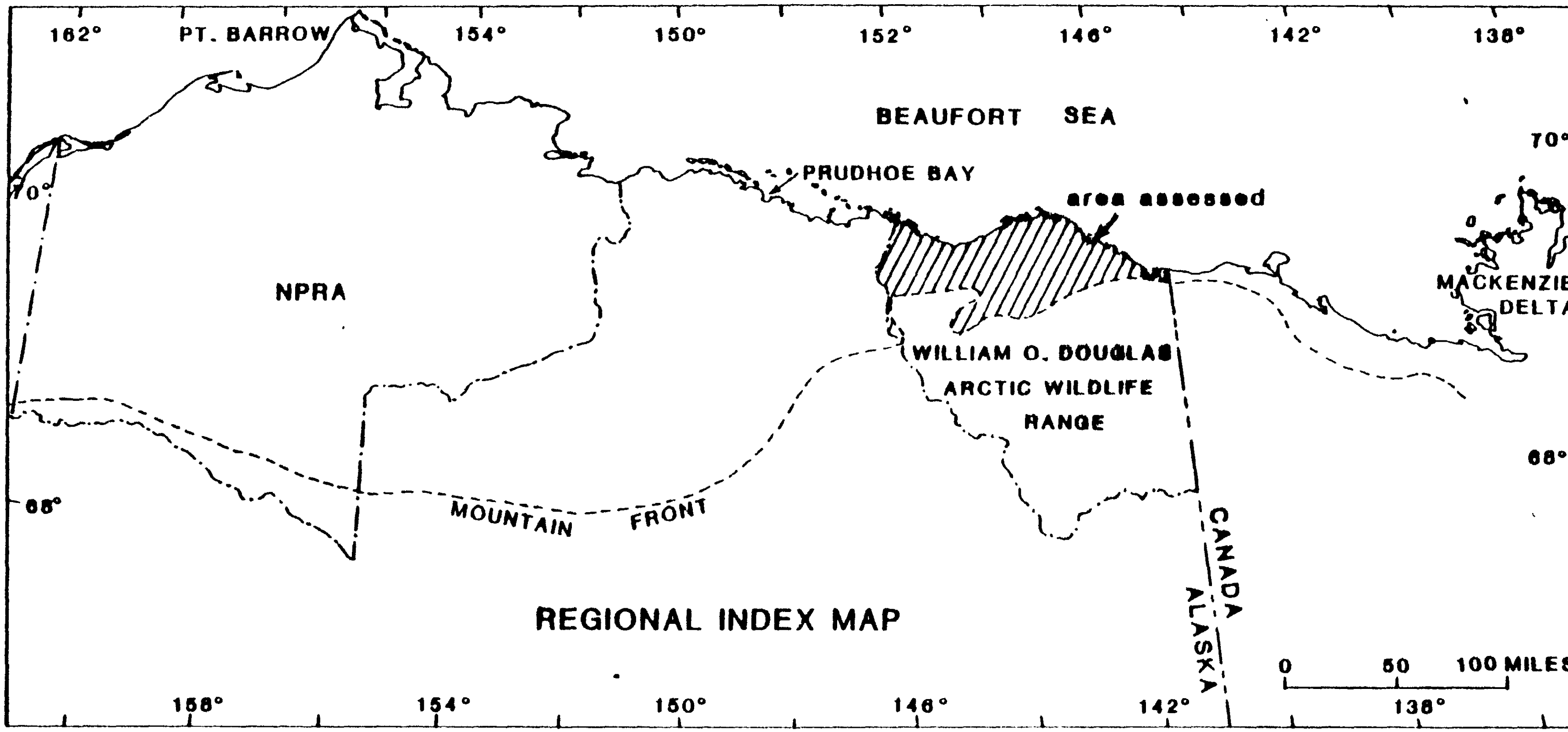


Figure 1 - Index map of northern Alaska and Canada showing location of the William O. Douglas Arctic Wildlife Range.

Estimating undiscovered hydrocarbon resources is difficult even when data are abundant. Unfortunately, within the Wildlife Range geological information is sparse consisting of only a proprietary aeromagnetic survey, a gravity survey, and surface geology. Data are more abundant adjacent to the Range and include surface geology, subsurface geology (several wells), and offshore reflection seismic profiles. Data for adjacent areas of Canada were generaoudly made available by the Geological Survey of Canada and Dome Petroleum Corporation and were incorporated into the assessment. One of the most valuable types of data for resource assessment is reflection seismic, but, as noted, there were no seismic data available for this area. In the absence of these data, geologists made interpretative judgments by projecting available information into the subsurface and by constructing one or more "models" describing the subsurface geology. Multiple subsurface interpretations compound the difficulty of resource appraisal.

Of singular importance to this assessment is the problem of truncation of many of the older Paleozoic and Mesozoic units. A period of uplift and erosion in either early Jurassic or earliest Cretaceous time may have removed all older, petroleum-prospective rocks from a large portion of the coastal plain area of the Wildlife Range. Neither the trend nor the areal extent of truncation is known; however it is certain that truncation affects to some degree 7 of the 10 plays. Cross sections were constructed illustrating a "maximum truncation" and "minimum truncation" case and thus were utilized when assessing the "number" of drillable prospects" attributed for each play.

The following sections of this report present the regional geologic setting of the Wildlife Range, the definition and petroleum geology of each play, play input parameters, a description of the play method, discussion of methodological problems, computer results of the assessment, discussion of the results and conclusions. The "Results" and "Conclusions" sections show a comparison with NPRA because the assessment of that area is the only other instance of the use of this methodology by the Department of the Interior, therefore providing a basis for relative quality evaluation of the WODAWR assessment.

REGIONAL GEOLOGY

The northern part of the Wildlife Range is located in an area of convergence and overlap of three sedimentary provinces--the Arctic Platform, the Colville Foredeep, and the Camden-Demarcation Basin. It lies also at the probable convergence of three large structural features--the Brooks Range fold belt, the Barrow Arch, and the Barrow Platform edge (see fig. 2). Because of its peculiar location the area contains a sequence of exposed rocks of almost all systems from Precambrian to Quaternary, which have been affected by a series of erosional unconformities that have removed parts of this rock sequence from large, but indeterminate areas during past geologic time (see figure 3).

Sedimentary Provinces

The Arctic Platform is the site of relatively thin, generally shallow marine or fluvial clastic and carbonate deposits of Mississippian to earliest Cretaceous age that were derived from land sources on and north of the platform - the Ellesmerian sequence of Lerand (1973). The Mississippian rocks at the base of this sequence rest with angular unconformity on Ordovician and Silurian rocks in NPRA and also to the east along the Arctic coast where the platform continues through the oil fields beneath the Camden Basin (Carter and Laufeld, 1975). A second large erosional unconformity is at the base of the Cretaceous rocks which, at Prudhoe Bay field lap northward across the eroded edge of all the older rocks in the sequence and locally rest on the lower Paleozoic Franklinian basement (Rickwood, 1970).

East of Camden Basin the Arctic Platform sequence is exposed (but not separately designated on fig. 2) throughout the Northeast Brooks Range fold belt, where the sub-Mississippian unconformity is ubiquitous and the sub-Cretaceous unconformity is evident at the northernmost mountain front (Reiser

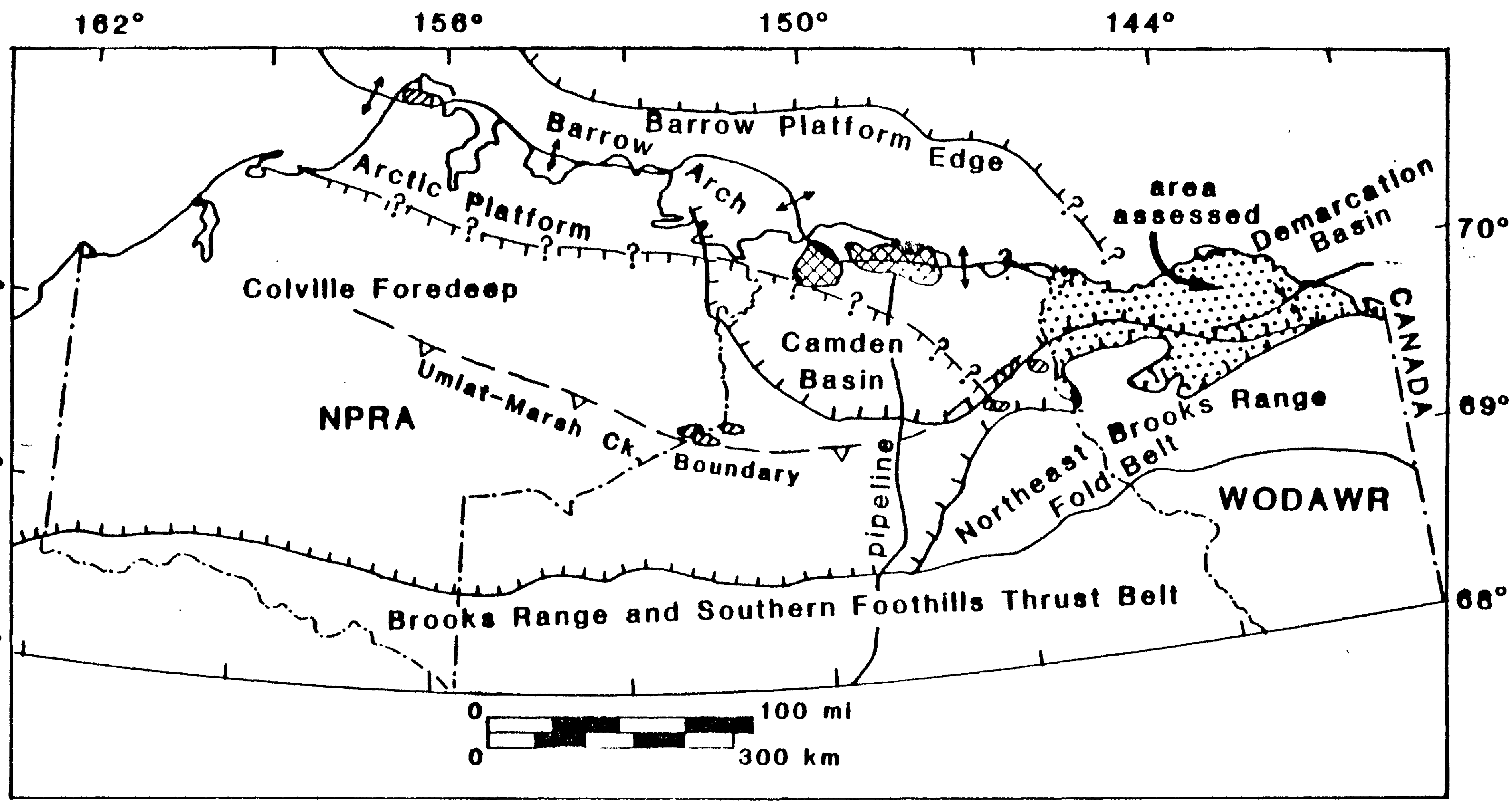


Figure 2 - Index map of northern Alaska showing location of geologic provinces, major structural features along the Arctic Coast, oil fields (cross-hatched) and gas fields (diagonal ruled), and NPRA and the William O. Douglas Arctic Wildlife Range.

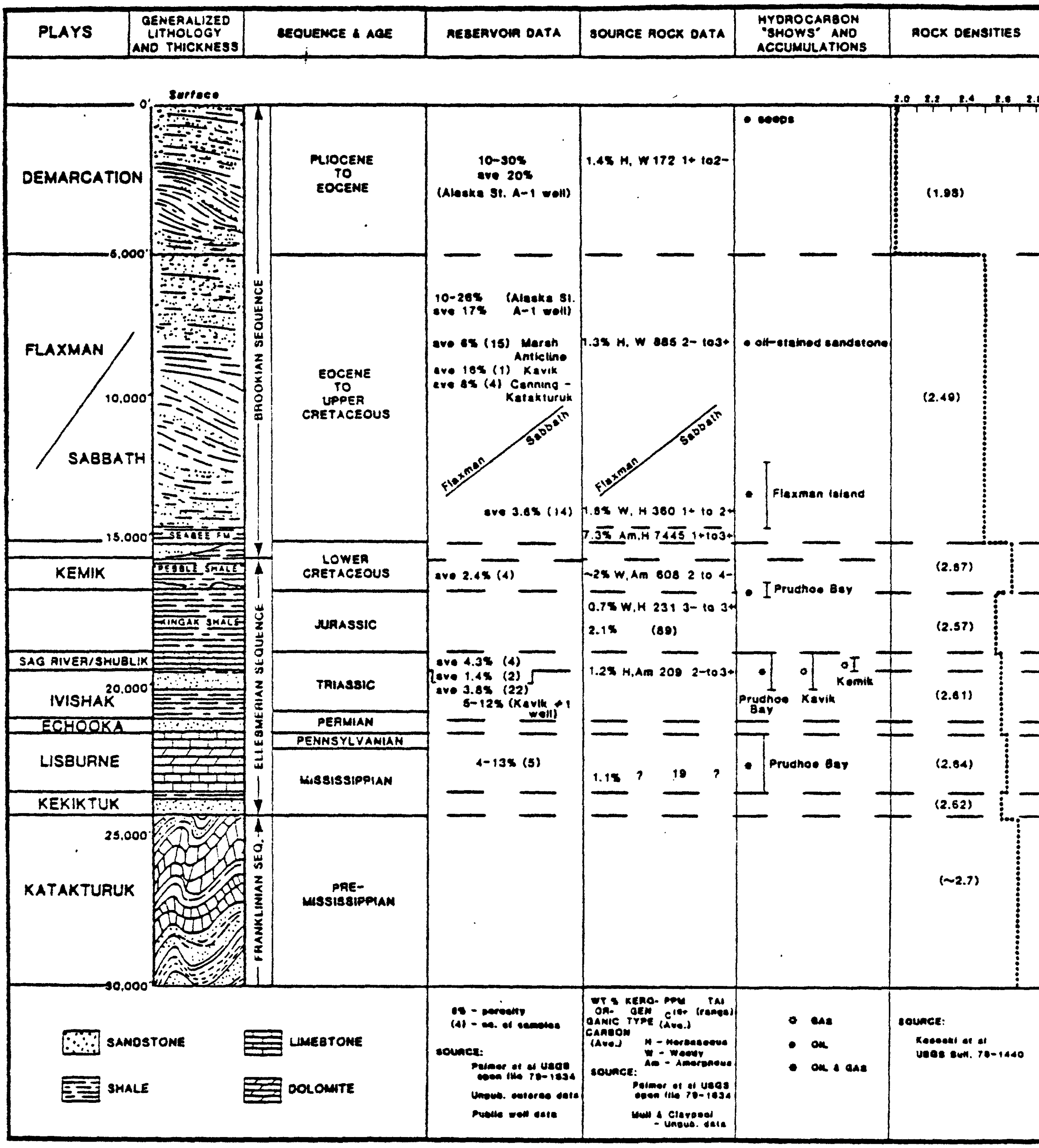


Figure 3 - Stratigraphic column and data summary for plays in the William O. Douglas Arctic Wildlife Range.

and others, 1971, 1978). Immediately east of the Wildlife Range, in Canada, two more unconformities are evident, having caused Upper Triassic rocks and Jurassic rocks to rest on basement over large areas (Norris, 1978).

The main part of the Colville Foredeep contains a very thick Brookian Sequence of Cretaceous fluvial and marine clastic deposits that were derived from the ancestral Brooks Range. These deposits prograded northward and eastward in two deltaic cycles, gradually filling the foredeep and lapping seaward across the Arctic Platform in NPRA during Early Cretaceous time and across the Arctic Platform beneath the Camden Basin in Late Cretaceous time (Rickwood, 1970; Morgridge and Smith 1972). These deposits are relatively thin where exposed in the Wildlife Range, at the east end of the foredeep, but may thicken northward.

The Camden and Demarcation Basins were further filled with a third thick deltaic unit of the Brookian Sequence composed of Tertiary fluvial and marine clastic deposits that prograded northward across the Cretaceous basin fill and spilled out across the present continental margin. The rocks of the Demarcation Basin are probably continuous eastward offshore with the Tertiary rocks of the Mackenzie Delta.

Structural Features

Northward directed overthrusting and folding began in the Brooks Range and its foothills in Late Jurassic or earliest Cretaceous time and has continued into the Tertiary. In the Wildlife Range the folding may have continued into the Quaternary. Overthrusts are the dominant structures in most of the Brooks Range and southern foothills, and bedding plane faults at depth uncouple the shallow folds in the foothills from the basement rocks as far north as the Umiat-Marsh Creek boundary (fig. 2) (Tailleur and others, 1978; Brosge and Tailleur, 1971). Thrust faults are less abundant in the Northeast Brooks Range, and vertical uplift seems dominant over horizontal movement along the mountain front. However, the fact that the Umiat-Marsh Creek structural front has been identified in the subsurface (Tailleur and others, 1978) immediately to the west of the Range suggests that within the Wildlife Range bedding plane thrusts may also underlie large folds north of the mountains such as Marsh Creek anticline (see figure 4).

The Barrow Arch (Rickwood, 1970; Grantz, and others, 1979) is believed to be the hingeline along which the rocks of the Arctic Platform sagged down to the north when the continental margin was rifted in Late Jurassic or Early Cretaceous time. The large unconformity beneath Lower Cretaceous rocks on the Arctic Platform may result from erosion on a block-faulted uplift that immediately preceeded this rifting (Rickwood, 1970). The Barrow Platform Edge (Grantz, pers. commun., 1980) is approximately the line of rifting. It marks the offshore edge of known Arctic Platform and basement rocks and is the line along which Tertiary and Cretaceous deposits drape over the edge of the Arctic Platform block and are involved in a series of down to basin faults.

The trends of the Barrow Arch and the Barrow Platform Edge converge toward the eastern end of the area in which they have been mapped by seismic methods. Grantz and others (1979) propose that these trends intersect. They believe that the Barrow Platform Edge comes onshore in the western part of the Wildlife Range, cuts across the Barrow Arch and continues eastward within the Wildlife Range. They also propose that rifting along this segment of the margin took place in Jurassic time. In this case, Jurassic deposits as well as Cretaceous and Tertiary deposits would have spilled across the platform edge into a deep basin within the northern Wildlife Range. Within that basin the Arctic Platform rocks that form the Barrow Arch would either be absent or be at very great depth.

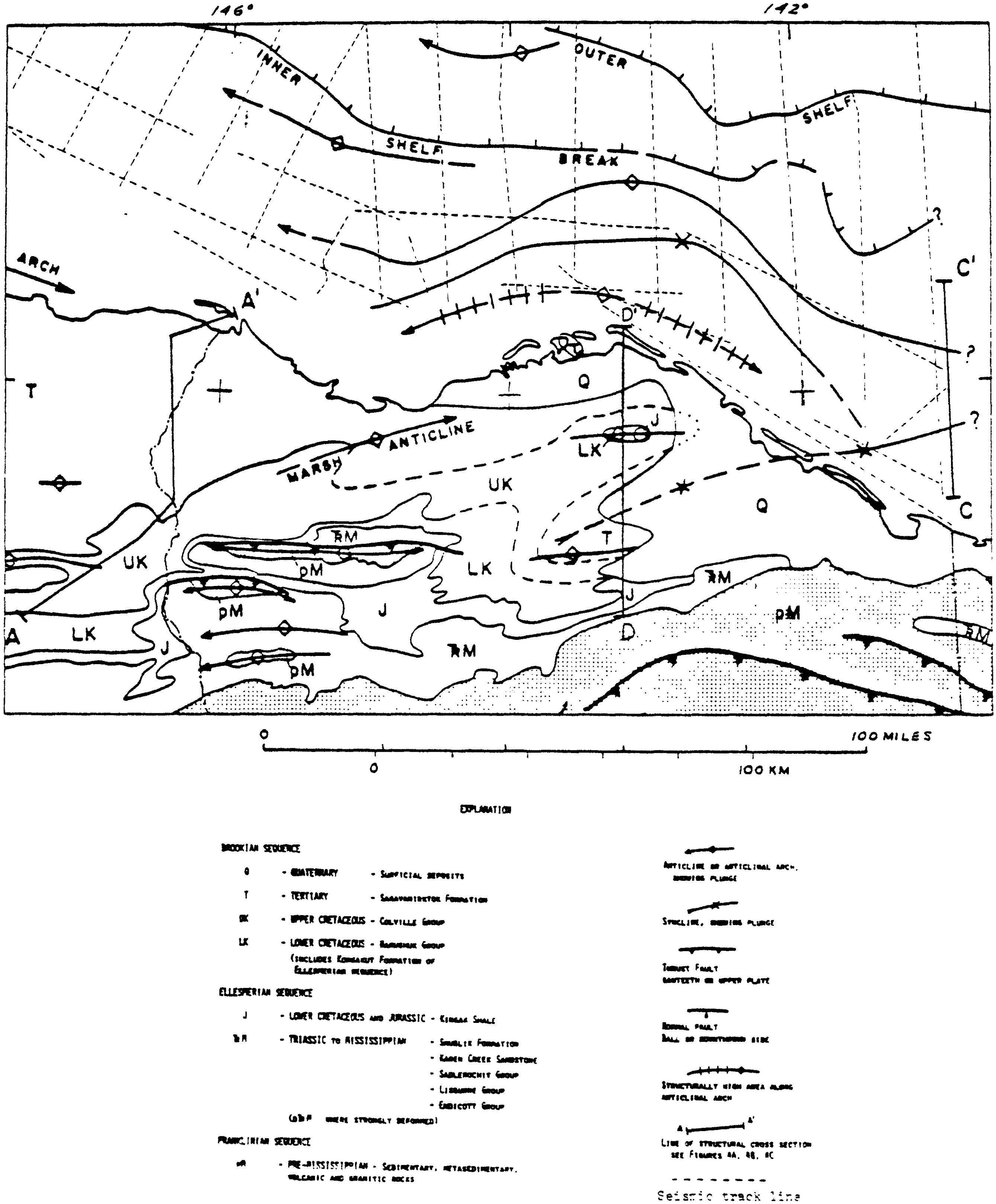


Figure 4 - Generalized geologic map of the William O. Douglas Arctic Wildlife Range from Grantz and Mull (1978), with offshore seismic lines added (S. May, written comm., 1980). Line D-D' shows location of cross sections in Figure 6 of this report.

On the other hand, Kososki and others (1978) suggest that a large high gravity anomaly in the northernmost part of the Wildlife Range (see figure 5) results from shallow basement rocks and that the rocks of the Arctic Platform are therefore present this far north.

Stratigraphy of Plays

Seven of the ten plays assessed in the Wildlife Range are in rocks related to the Arctic Platform. Five of these plays have also been designated as plays in NPRA, and of these 5, 3 are known to be reservoirs in the Prudhoe Bay field and one is similar to the reservoir in the Kuparuk River field.

The youngest of these plays, the Kemik, is a locally derived sandstone above the Lower Cretaceous unconformity. This sand is similar in occurrence to the Jurassic Kuparuk River sandstone that forms a reservoir immediately below the unconformity in the Kuparuk River field. The play in the upper Triassic Shublik Formation and Sag River Sandstone is in a blanket deposit of organic-rich shale and thin limestone and sandstone that is included in the main Prudhoe Bay reservoir. The Ivishak play, which occurs in the main Prudhoe Bay Reservoir, is a fluvial sand and conglomerate deposited near the north edge of a lower Triassic delta system that was built southward across the Arctic Platform. The underlying Echooka play is in Permian near-shore sandstones that are poorly developed at Prudhoe Bay and in NPRA, but are much thicker in the Wildlife Range. The play in the underlying Lisburne Group is in shallow-water carbonate rocks that blanket the North Slope and that contain part of the Prudhoe Bay reservoir, although these reservoirs have not yet been produced. The Kekiktuk play, in sporadically developed fluvial sandstone and conglomerate of Mississippian age that rests on basement, is also considered to be part of a play in NPRA even though it is not a reservoir at Prudhoe

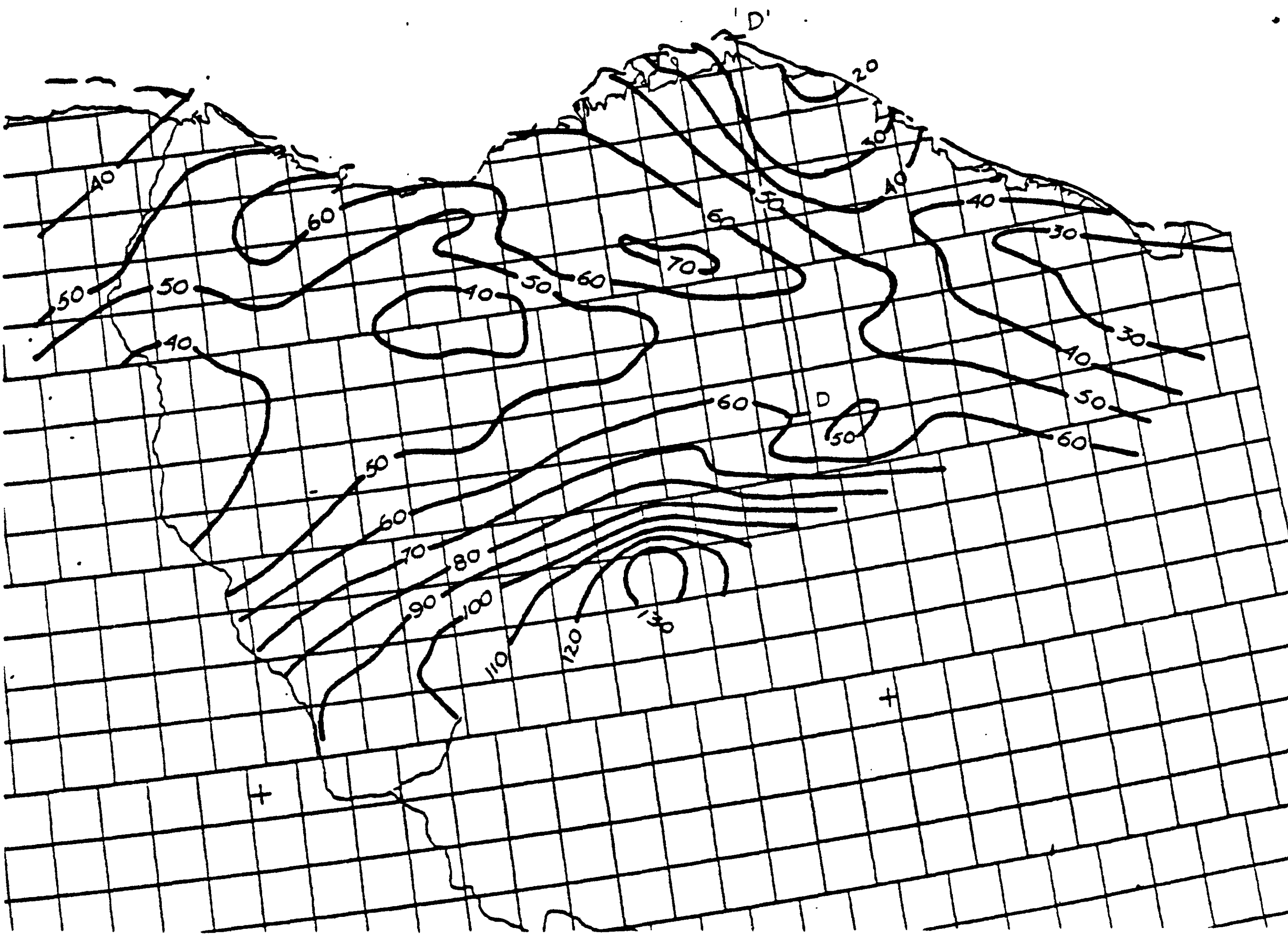


Figure 5 - Bouger gravity map of the northern part of the William O. Douglas Arctic Wildlife Range, after Kososki and others, (1978). Contour interval = 10 milligals. All contoured gravity values are negative.

Bay. The Katakturuk play, in Devonian and Silurian(?) dolomite within the Arctic Platform basement, is in older carbonate rocks that are known only near the Wildlife Range.

The remaining 3 plays are mainly in the Tertiary fluvial and marine clastic rocks of the Camden and Demarcation Basins that overlapped north across the Arctic Platform and across the continental margin. These rocks are virtually absent from NPRA and are present, but are not reservoirs, at Prudhoe Bay. They are reported to be reservoirs east of Prudhoe Bay where they overstep the Barrow Arch, and are the chief reservoirs in the Canadian oil and gas fields of the Mackenzie Delta.

Many of the plays on the Arctic Platform are related to the lower Cretaceous unconformity. The potential reservoir sands of the Kemik play were deposited on the unconformity. The inferred oil in the underlying Triassic to Mississippian plays may have been derived from Cretaceous shales that are in contact with these rocks along the unconformity (Morgridge and Smith, 1972; Seifert and others, 1979). A charge of oil from the Cretaceous shales is required for the Katakturuk play in the overmature basement rocks. In addition, it seems possible that higher porosities in the older reservoir rocks may be related to exposure of these rocks at the unconformity.

No Lower Cretaceous Albian rocks of the Colville foredeep are regarded as plays in the Wildlife Range even though some of the most promising plays in NPRA are in those rocks. Albian rocks are virtually absent in the Prudhoe Bay field, and are now known to be thin or absent in the outcrops in the northern Wildlife Range. Although thick sections of rocks of supposed Albian age have been described along Sabbath Creek in the Wildlife Range (Detterman et al., 1975, figures 9 and 10), pollen samples from these same rocks have now shown that most of them are Paleocene (Palmer and others, 1979).

Alternate Geologic Models

The Mississippian to Triassic rocks of the Arctic Platform include the major Prudhoe Bay reservoir and 5 of the 10 plays defined for the Wildlife Range. However, it is uncertain how far north of the mountain front any of these rocks are present within the Wildlife Range.

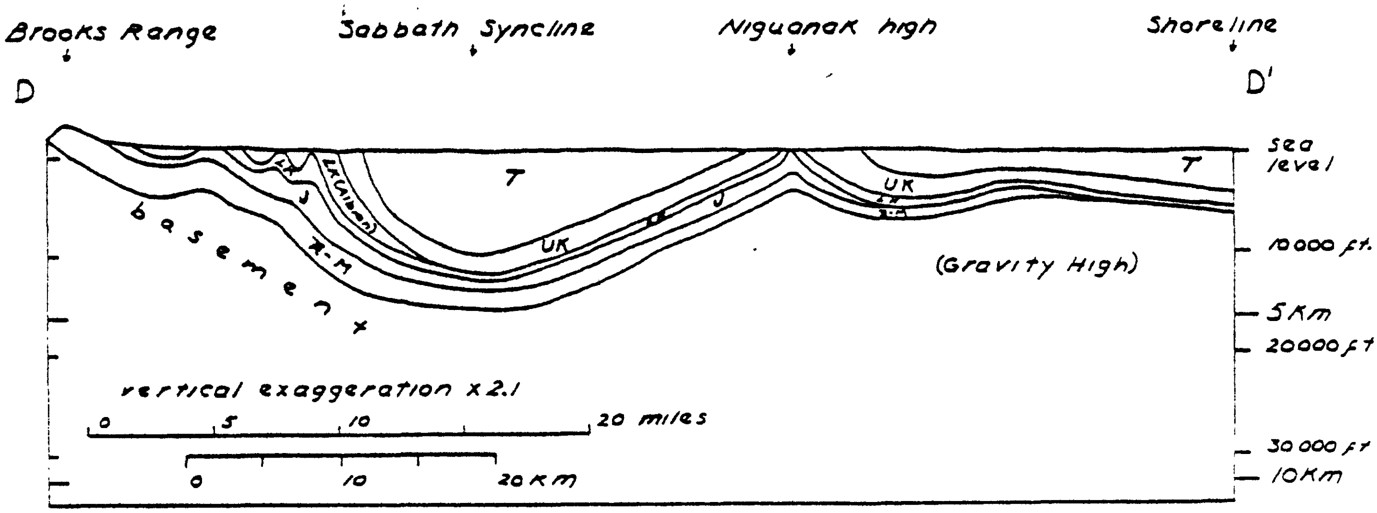
Pre-Cretaceous erosion has removed all of these rocks from some large areas west of the Wildlife Range, pre-Jurassic erosion has removed all of these rocks from large areas in Canada, and pre-Cretaceous erosion has locally removed Upper Triassic and Jurassic rocks within the Wildlife Range (Reiser and others, 1971, 1978). In addition, the hypothesis of Grantz and others (1978) is that neither the platform deposits nor the basement upon which they were deposited are present in the northern part of the Wildlife Range except possibly at great depth.

Three possibilities have been suggested:

1. The Arctic Platform basement and all the overlying Mississippian to Triassic deposits are present north of the mountains (Kososki and others 1978).
2. The Arctic Platform basement may be present, but most of the overlying Mississippian to Triassic rocks were eroded away in the area north of the mountains during Jurassic or Early Cretaceous time (Grantz and Mull, 1978).
3. The entire block of Arctic Platform basement and overlying Mississippian to Triassic rocks was down dropped and rifted away from the area in Jurassic time (Grantz and others 1979).

Data on the older rocks in the area in question are few and ambiguous. The gravity anomaly has been interpreted as evidence of shallow basement by Kososki and others (1978) or as the result of a large thrust fold with Cretaceous and Jurassic rocks in the center that are denser than the surrounding Tertiary deposits (Grantz and Mull 1978). The occurrence of an anticlinal outcrop of Jurassic rocks about 30 km south of the coast (Reiser and others, 1978) can be interpreted to mean either that the Arctic Platform rocks are present in a normal anticline or (Grantz and Mull 1978) that the older Arctic Platform rocks have been removed by Jurassic erosion and the Jurassic outcrop represents the core of a diapiric thrust fold developed in a thick Jurassic deposit.

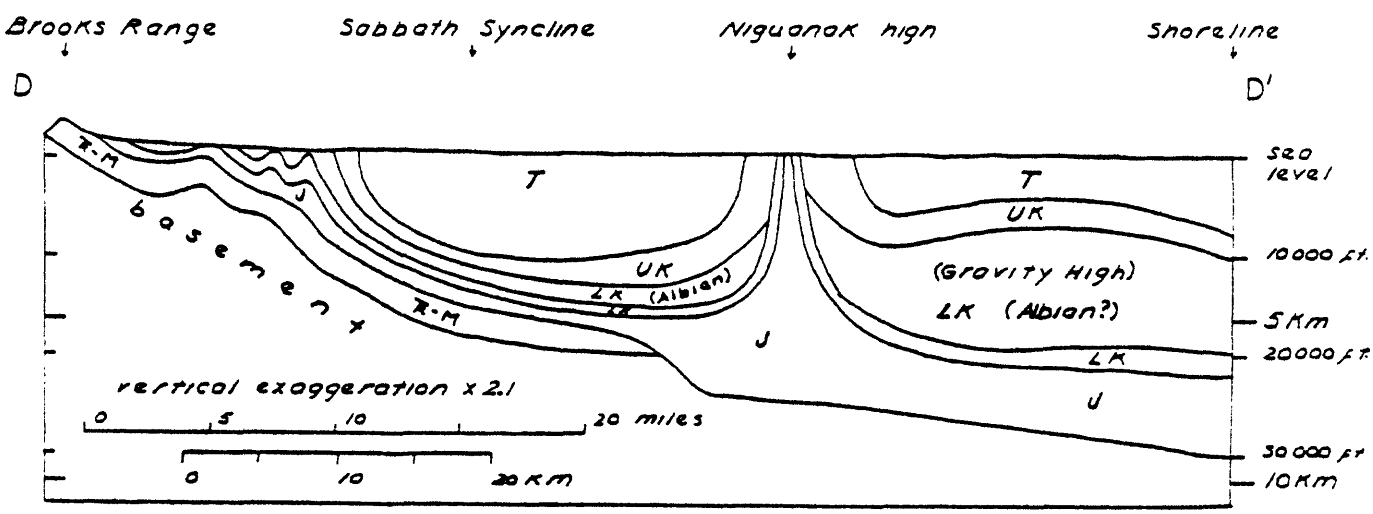
The two extremes of this range of possibilities (1 and 3) are illustrated by hypothetical cross sections (fig. 6) and basement depth maps (fig. 7). In making the play analyses it was assumed that these two possibilities were equally likely and that consequently there was a 50-50 chance that the Mississippian to Triassic rocks were absent in the northern part of the play area.



CROSS SECTION ILLUSTRATING THE HYPOTHESIS THAT THE GRAVITY HIGH NEAR BARTER ISLAND IS CAUSED BY SHALLOW BASEMENT.

Cross section also illustrates the hypothesis that the Triassic to Mississippian rocks are truncated by Lower Cretaceous rocks on the gravity high as they are on the Barrow Arch.

Cross section fits hypothetical basement depth Map A.



CROSS SECTION ILLUSTRATING THE HYPOTHESIS THAT THE GRAVITY HIGH NEAR BARTER ISLAND IS CAUSED BY A GREAT THICKNESS OF PRE-UPPER CRETACEOUS MESOZOIC ROCKS.

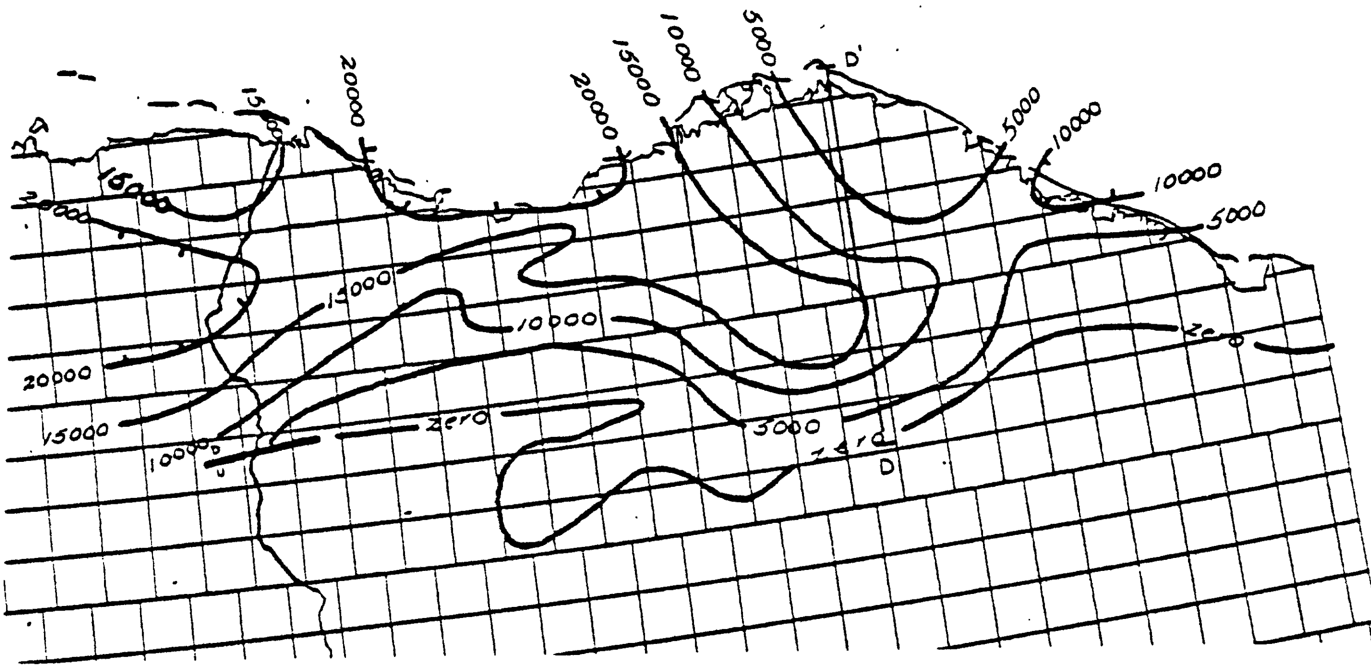
Cross section also illustrates the hypotheses that the outcrop of Jurassic rocks near Niguanak Creek is a diapir, and that the continental margin in Jurassic time was near Niguanak Creek.

Cross section fits hypothetical basement depth Map B.

Figure 6 - Hypothetical geologic cross sections of the northern part of the William O. Douglas Arctic Wildlife Range. Location of line of section is shown on Figures 4, 5, and 7.

HYPOTHETICAL BASEMENT MAP A

Depth to basement in feet assuming shallow basement under the gravity high near Barter Island.



HYPOTHETICAL BASEMENT MAP B

Depth to basement in feet assuming deep basement under the gravity high near Barter Island

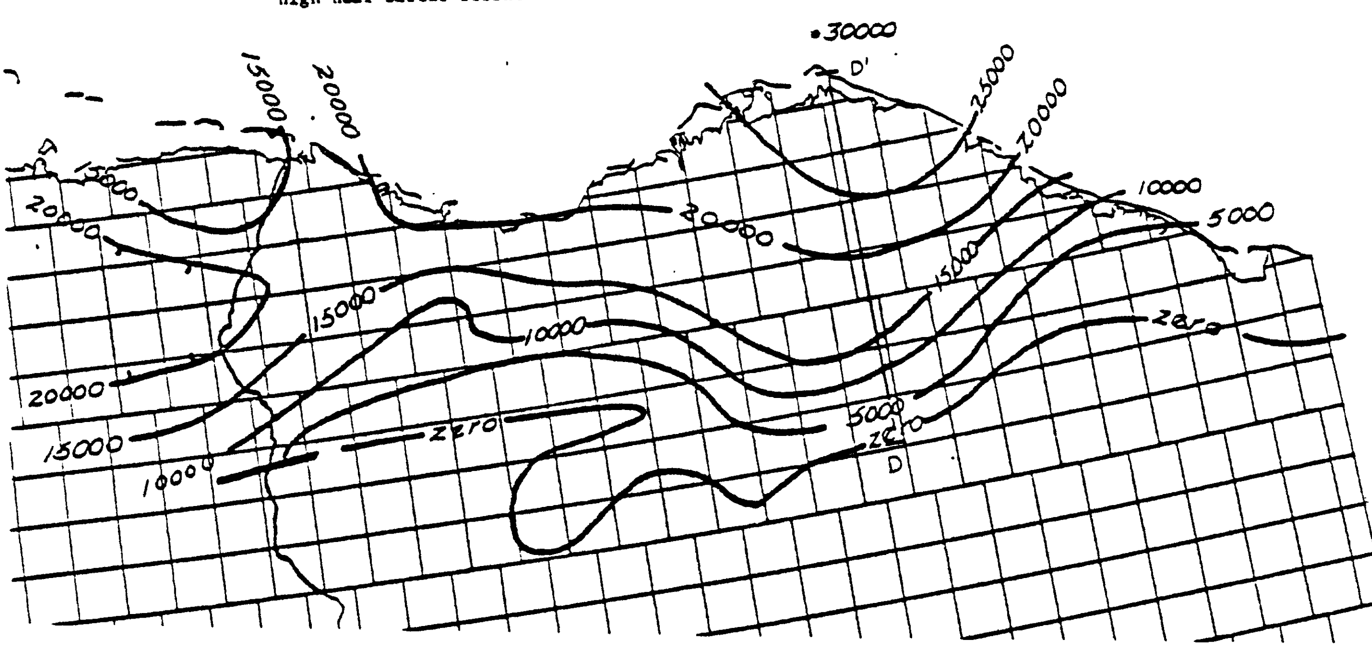


Figure 7 - Maps showing hypothetic depths to basement in the northern part of the William O. Douglas Arctic Wildlife Range.

PLAY ANALYSIS METHOD

General Discussion

The Office of Minerals Policy and Research Analysis, Department of the Interior, in cooperation with the Geological Survey, developed a method using the play as the basic unit of analysis (White, 1979). This method is a modification of that used by the Canadian government in estimating Canada's petroleum resources (Canada Dept. of Energy, Mines and Resources, 1977; Roy and others, 1975). The play approach divides the geological characteristics of potential hydrocarbon accumulations into three categories: play-specific, prospect-specific, and reservoir-specific attributes. Subjective probability judgments for each of the three sets of characteristics are made by experts familiar with the local geology. A Monte Carlo method is then used to combine the judgment values to give probability distributions of pool size and in-place hydrocarbon values for each play. Further use of the Monte Carlo method provides an aggregation of all plays to give a total resource estimate.

Play-specific attributes consist of geologic characteristics common to the entire play. They include hydrocarbon source, timing, migration, reservoir rock, reservoir rock type, hydrocarbon mix (oil and gas), and number of prospects (see appendix 3 for definitions). A probability of favorable occurrence is estimated for each of the first four items. Reservoir rock type is determined to be either sandstone or carbonate rock throughout the play. Hydrocarbon mix is an estimate of relative preponderance of gas or oil accumulations within the play. Number of prospects is estimated as a probability distribution expressed for seven fractiles. The product of the first four probabilities is termed the marginal play probability--the joint probability that all of the regional geologic characteristics necessary for the accumulation of hydrocarbons in the play area are simultaneously favorable. The joint occurrence of these play-specific attributes is a necessary but not sufficient condition for the existence of hydrocarbon accumulations in the play.

Prospect-specific attributes are the geologic characteristics common to the individual prospects within the play. They include the existence of a trap minimum effective porosity and "hydrocarbon accumulation." This latter term expresses the favorable relationship of source rock to reservoir rock and time of hydrocarbon generation to trap formation. A probability of favorable occurrence is estimated for each item, based on the condition that all of the play-specific attributes are favorable. The product of the three prospect-specific probabilities is the joint probability that a prospect contains petroleum, given that the play is favorable. This is defined as the conditional deposit probability (conditional on favorable play geology). The product of the marginal play probability and the conditional deposit probability is the probability that a given prospect will contain hydrocarbons.

Reservoir-specific attributes are those characteristics which determine the volume of petroleum present in an individual accumulation in the play. They include area of closure, reservoir thickness, effective porosity, trap fill and reservoir depth. Each characteristic is assessed as a probability distribution and reported for 7 fractile levels.

Utilizing the three basic sets of probability judgments recorded on the appraisal data forms, a Monte Carlo simulation is used to calculate probability distributions of the in-place resources and pool sizes for each play. An additional Monte Carlo aggregation of these resource distributions for each play provides the total in-place resource distributions and the total pool size distributions for the Wildlife Range.

METHODOLOGY PROBLEMS

Instructions to evaluate the WODAWR using the same methodology as that used in the NPRA assessment have been carried out as closely as possible, including the same OMPRA computer program. However, the program and associated definitions for input data were developed for NPRA where the geology is fairly well known from an extensive grid of seismic data and numerous exploratory wells. This allows distribution for such input parameters as the number of prospects, prospect size, reservoir thickness, and porosity to be developed from an actual data base. Also the play boundaries are defined from the same data base. In the WODAWR, where there are no seismic data or subsurface geological information, the three critical input distributions must be subjectively developed and, therefore, are primarily based on analogs and the experience of the geologists making the assessments. This was a "first-time" experience for the Geological Survey staff in this type of assessment where a good set of analog data for this methodology was not available. The distribution for prospect size, number of prospects, and trap fill were the most difficult to estimate and have a high degree of uncertainty. Fortunately some analog data were available from the Geological Survey of Canada for Wildlife Range plays equivalent to those in the MacKenzie Delta and from the NPRA studies made by the U.S. Geological Survey for plays in the Wildlife Range that were similar to those in NPRA. Additional studies and research are needed to provide better sets of analog data from known plays if the play-analysis method is to be developed further for use in frontier areas. The need for and the importance of this analog data set is inversely proportional to the size of the data base in the area being appraised.

In using the play-analysis method, it is assumed that all the potential plays have been identified and adequately described. Exploration often discovers unexpected resources, even in well explored basins. In frontier areas, where the subsurface geology is highly speculative, it is often difficult to identify and adequately describe all of the plays.

In the Monte Carlo simulation it is assumed that parameters assessed in each play are independent and individual plays are also assumed to be independent. Some of the play parameters, which are probably not independent, are: number of prospects and area of closure, area of closure and trap fill, and trap fill and reservoir thickness. An example of dependency between plays, would be the Ellesmerian plays in WODAWR. All of the Ellesmerian reservoirs may be truncated by the Lower Cretaceous Jurassic unconformity and their presence or absence on a given prospect would be highly dependent. Also, since the Ellesmerian reservoirs are generally conformable, the trap existence, number of prospects and area of closure would be dependent between plays. These dependency problems, which are inherent in the play method, may have a major impact on the ranges of the probability distributions; therefore, mean estimates and the central portions of the resource distribution (i.e., the 25% to 75%) may have a higher reliability than values at the extreme ends of the curves (i.e., the 1% and 99% or the 5% and 95%).

PLAY DESCRIPTIONS

In the assessment of the Wildlife Range, plays were defined on the basis of individual reservoir units in contrast to the standard play definition of one or more prospects (seismically mapped stratigraphic or structural traps) in a common or relatively homogeneous geologic setting. Definition of plays by reservoir interval, or stratigraphic unit, was done because of the absence of seismic data necessary to map prospects and because it is easier to assess the play input parameters by reservoir intervals. Plays include both structural and stratigraphic traps. Where a single reservoir interval shows pronounced lateral changes in geologic characteristics, two plays were recognized, for example the Flaxman and Sabbath plays.

Play boundaries were chosen to coincide with the probable limits of the reservoir unit. Boundaries shown on the play maps have been shifted to the nearest township line for ease of plotting and calculating areas. The southern boundary of each play approximates the outcrop of each reservoir unit. The northern boundary of each play approximates the truncation edge of the reservoir unit where it can reasonably be inferred, such as in the northwest corner of the Range adjacent to numerous wells. In the eastern portion of the Range most pre-Cretaceous reservoirs (plays) are probably affected by truncation but the location of the truncation edge is unknown. For these plays the northern play boundary follows the coastline to allow for the possibility of little or no truncation. An alternative possibility of a truncation edge much farther south was considered in the assessment of each of these plays in the number of drillable prospects.

Descriptions of each play and its petroleum geology, the oil and gas appraisal data form that records the Committees subjective estimates, and the computer - generated estimates of undiscovered in-place oil and gas resources are presented in Appendix 1. Much of the data utilized in making the assessment are summarized in figure 3.

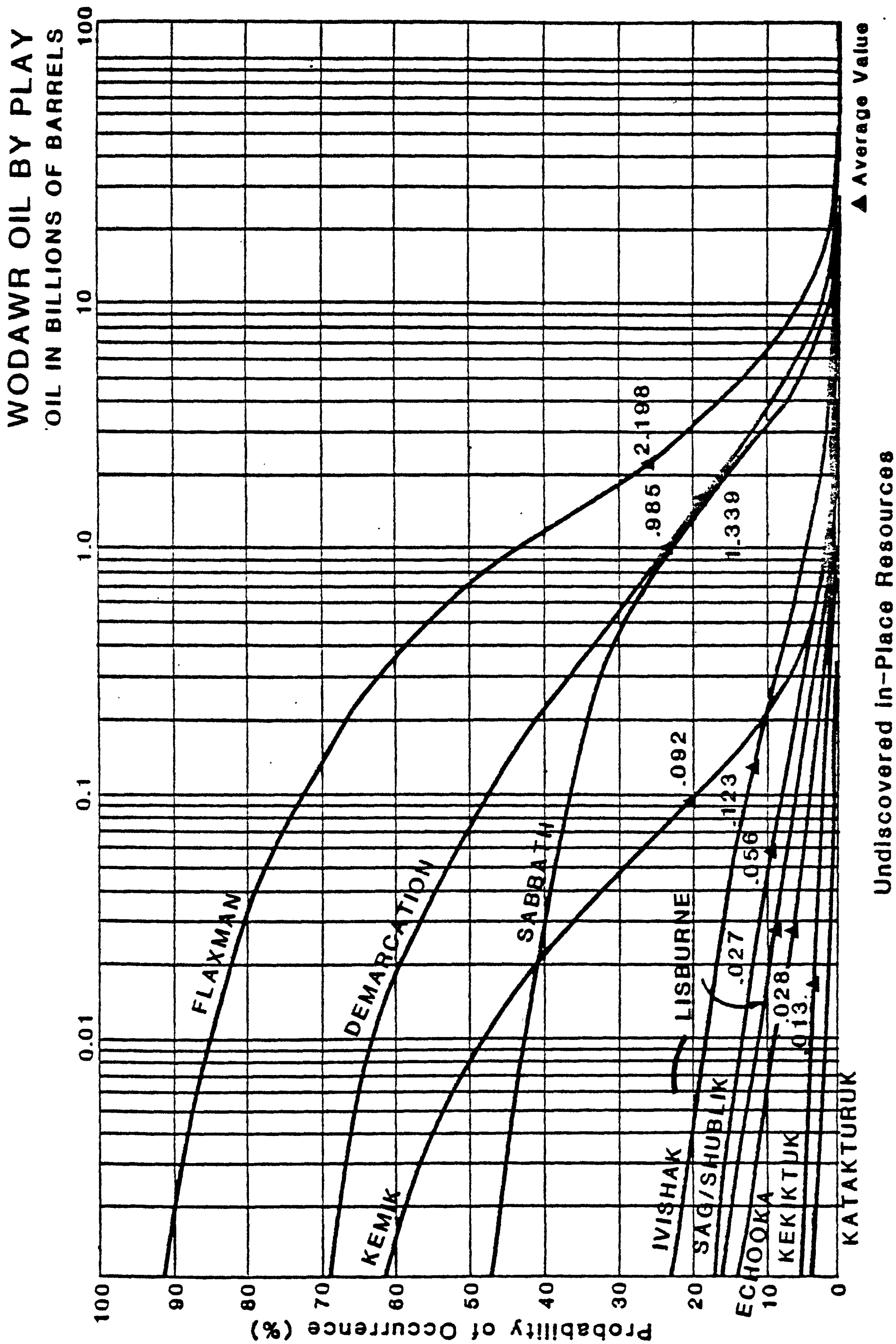
RESULTS

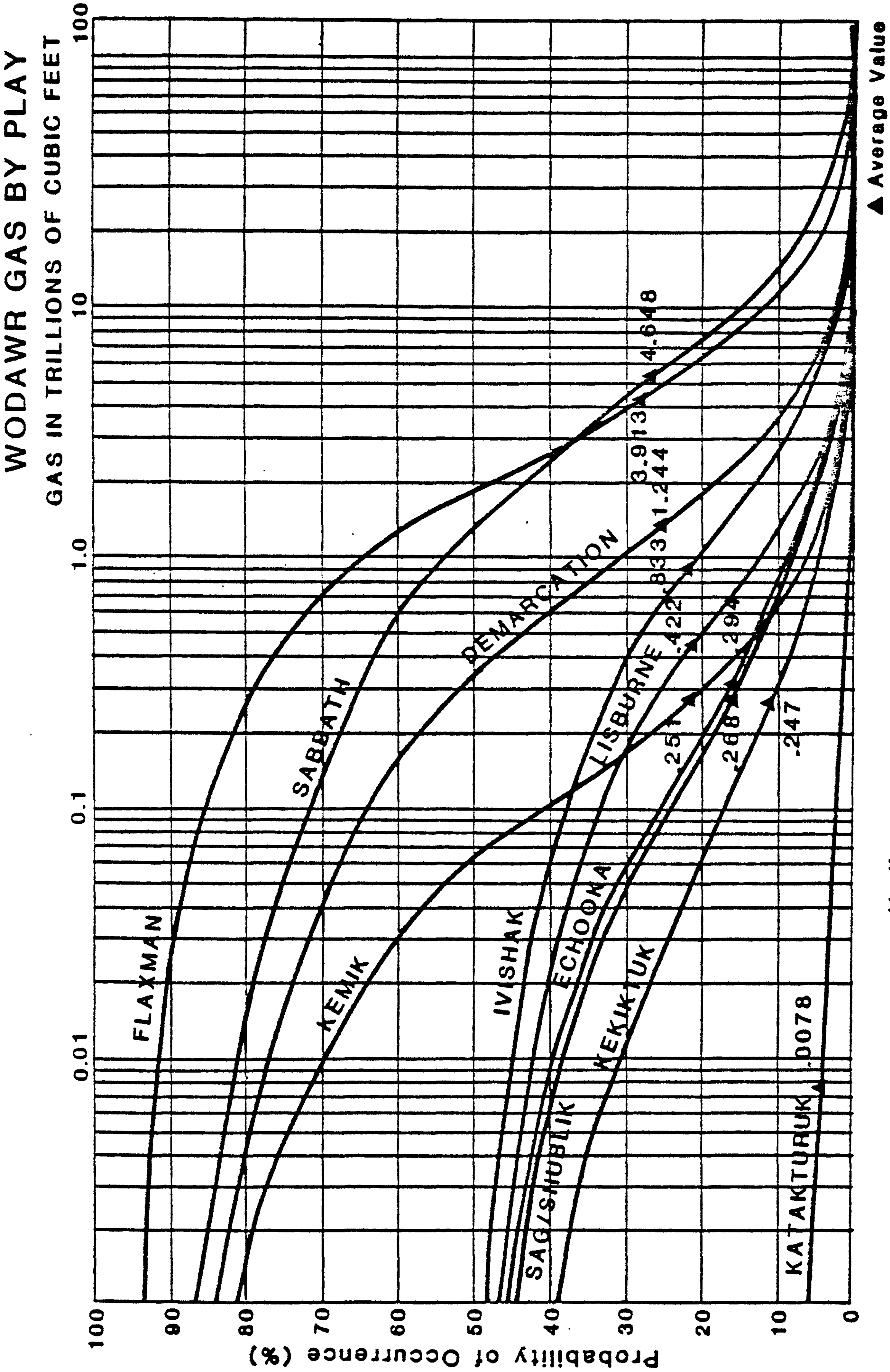
Undiscovered In-Place Oil and Gas Resource Appraisals using the Play-Analysis Method.

Undiscovered in-place oil and gas resource probability distributions are generated from the assessed geologic parameters shown on the play analysis forms in Appendix 1. These resource numbers are aggregated from a 3000 pass Monte Carlo simulation by the OMPRA computer resource model. In-place oil and gas probability distributions for undiscovered resources are computed for each play, and then resource distributions for all the plays are aggregated together to produce the total resource distributions for the entire area assessed in the Wildlife Range.

Undiscovered in-place oil and gas resource probability distributions for each play are shown on figures 8 and 9 respectively. At any probability level the value is estimated that at least that quantity of resources will occur. Computer print-outs from which play distributions were constructed are in Appendix 2. The undiscovered in-place gas resource probability distributions for each play contain estimated gas from gas pools (non-associated gas) and gas estimated to be dissolved in oil in the oil pools (associated gas). The number of gas pools in each play is estimated by the computer model from the geologic assessment of the gas/oil mix shown on the play assessment form in Appendix 1.

Figure 10 shows the probability distribution for the total in-place undiscovered oil resources for the coastal plains portion of the Wildlife Range. Also shown on the figure are the aggregated undiscovered oil distributions for the Tertiary plays (Demarcation, Flaxman, and Sabbath) and the Mesozoic-Paleozoic plays (all others) in the Wildlife Range. The Mesozoic-Paleozoic plays in the Wildlife Range are in units that are stratigraphically equivalent to units in NPRA in which plays have been


WODAWR OIL BY PLAY
OIL IN BILLIONS OF BARRELS
0.01
0.1
1.0
10
100
FLAXMAN
DEMARCATION
SABBATH
KEMIK
LISBURNE
IVISHAK
SAG/SHUBLIK
ECHOOKA
KEKIKTUK
KATAKTURUK
2.198
.985
1.339
.092
.123
.056
.027
.028
.013
▲ Average Value
Undiscovered In-Place Resources
Probability of Occurrence (%)
100
90
80
70
60
50
40
30
20
10
0


WODAWR GAS BY PLAY
GAS IN TRILLIONS OF CUBIC FEET
0.01
0.1
1.0
10
100
FLAXMAN
SABBATH
KEMIK
DEMARCATION
IVISHAK
LISBURNE
ECHOOKA
SAG/SHUBLIK
KEKIKTUK
KATAKTURUK
3.913
4.648
1.244
.833
.422
.294
.251
.268
.247
.0078
▲ Average Value
Undiscovered In-Place Resources
Probability of Occurrence (%)
100
90
80
70
60
50
40
30
20
10
0

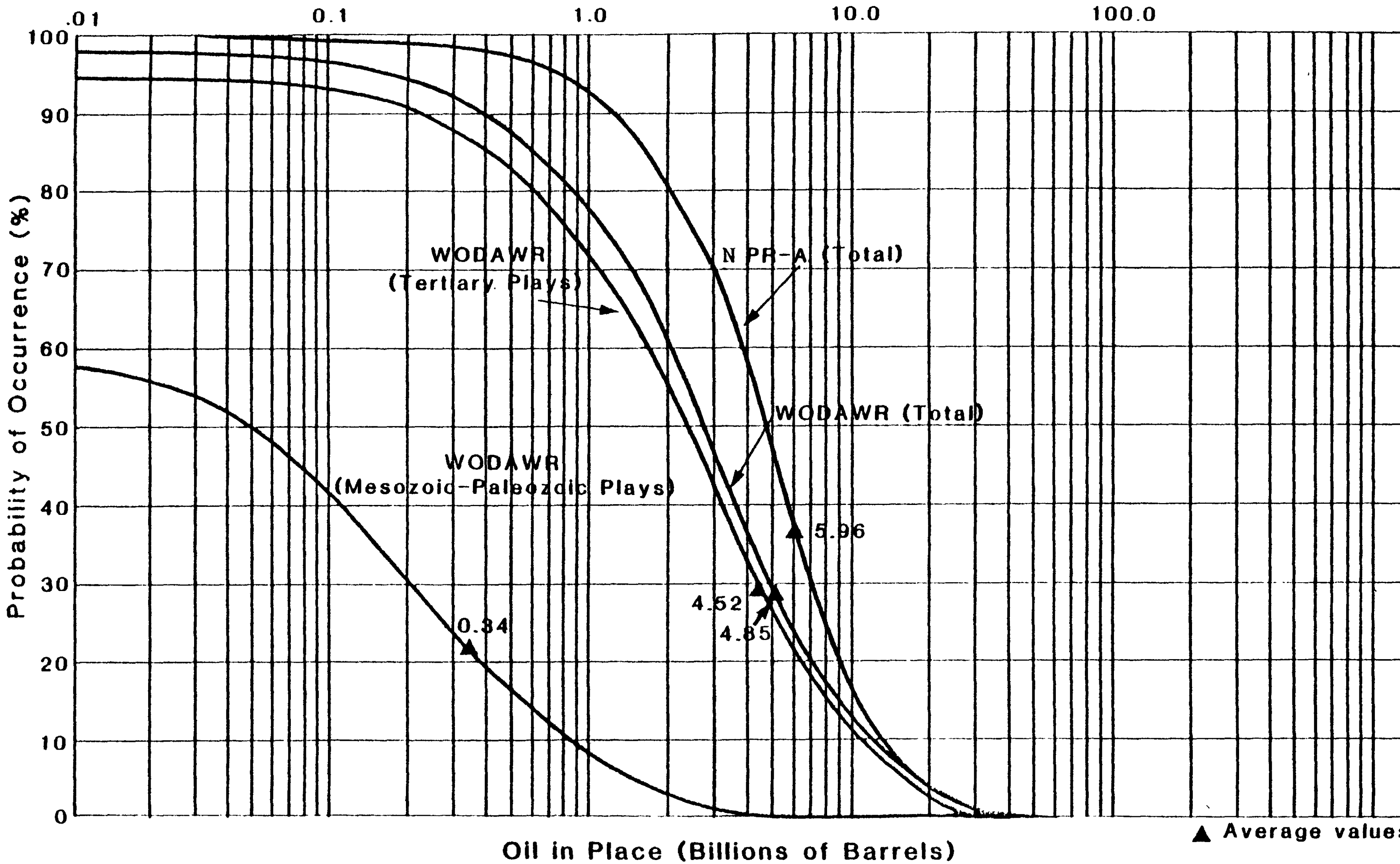
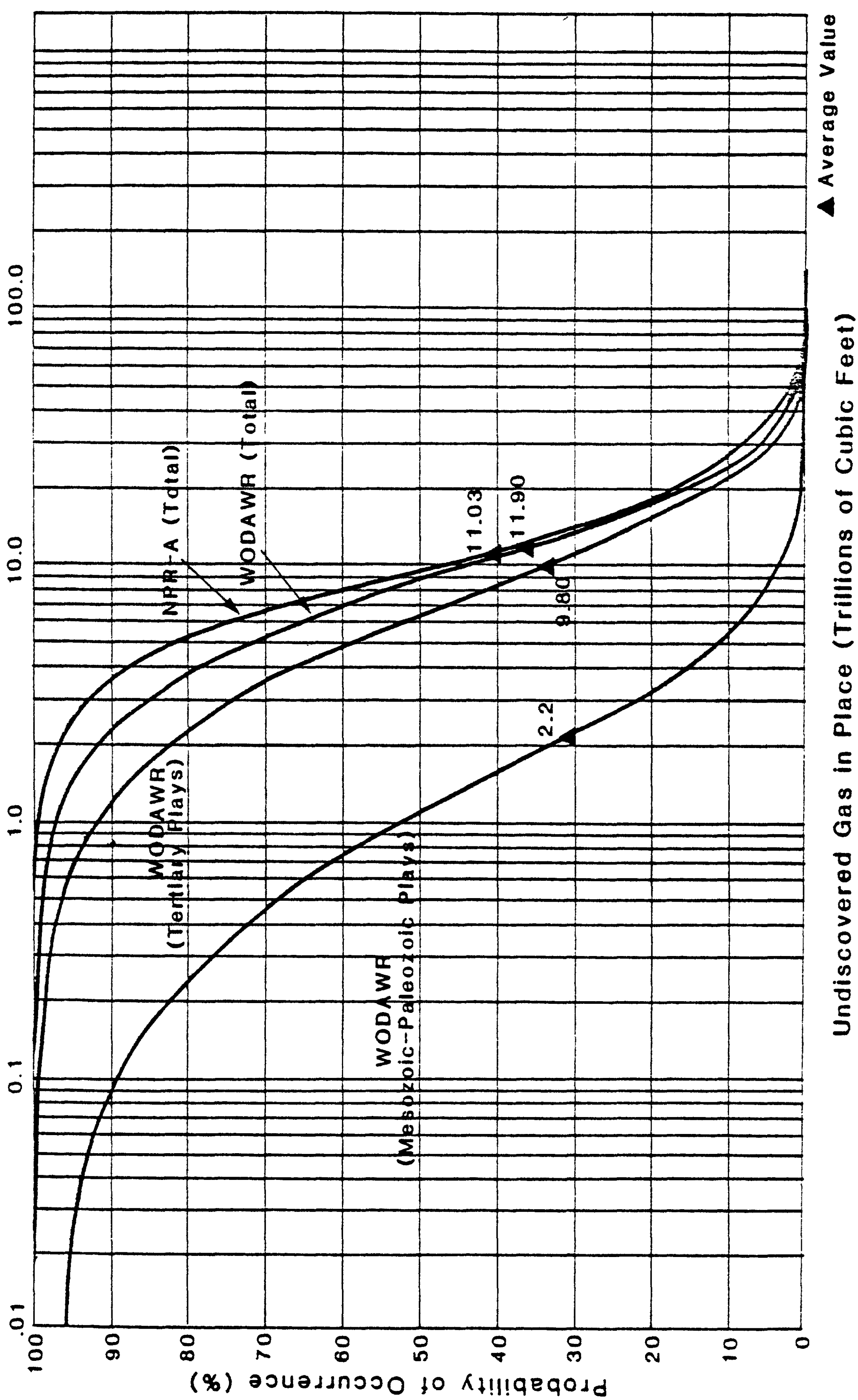


Figure 10 - Estimated undiscovered oil in-place in WODAWR and NPRA.

identified and assessed. The Mesozoic-Paleozoic resource curves for the Wildlife Range can be used to compare estimated undiscovered oil resources in the Wildlife Range with estimated undiscovered oil resources in NPRA (see figure 10) from oil and gas pools that are in equivalent strata. It should be noted that the comparisons made with NPRA are of the quantitative assessment of the geologic resource, and therefore the distributions shown for NPRA are also derived from 3000 passes by the OMPRA resource model which are based on the USGS May 22, 1980, update of the NPRA play parameters. These numbers will differ from results of the OMPRA economic model runs for the same update to be published by the Office of Mineral Policy Research and Analysis, DOI, because the resource quantities derived from the economic model runs are the result of only 150 computer passes. The curves on figure 10 show that the great bulk of the oil assessed in the Wildlife Range is assessed to be in the Tertiary plays, which are equivalent in age to strata now being explored in the Mackenzie Delta area of Canada. These same plays do not exist in NPRA, but some of these plays are now being explored in the Prudhoe Bay area immediately west of the Wildlife Range with an oil discovery reported at Flaxman Island.

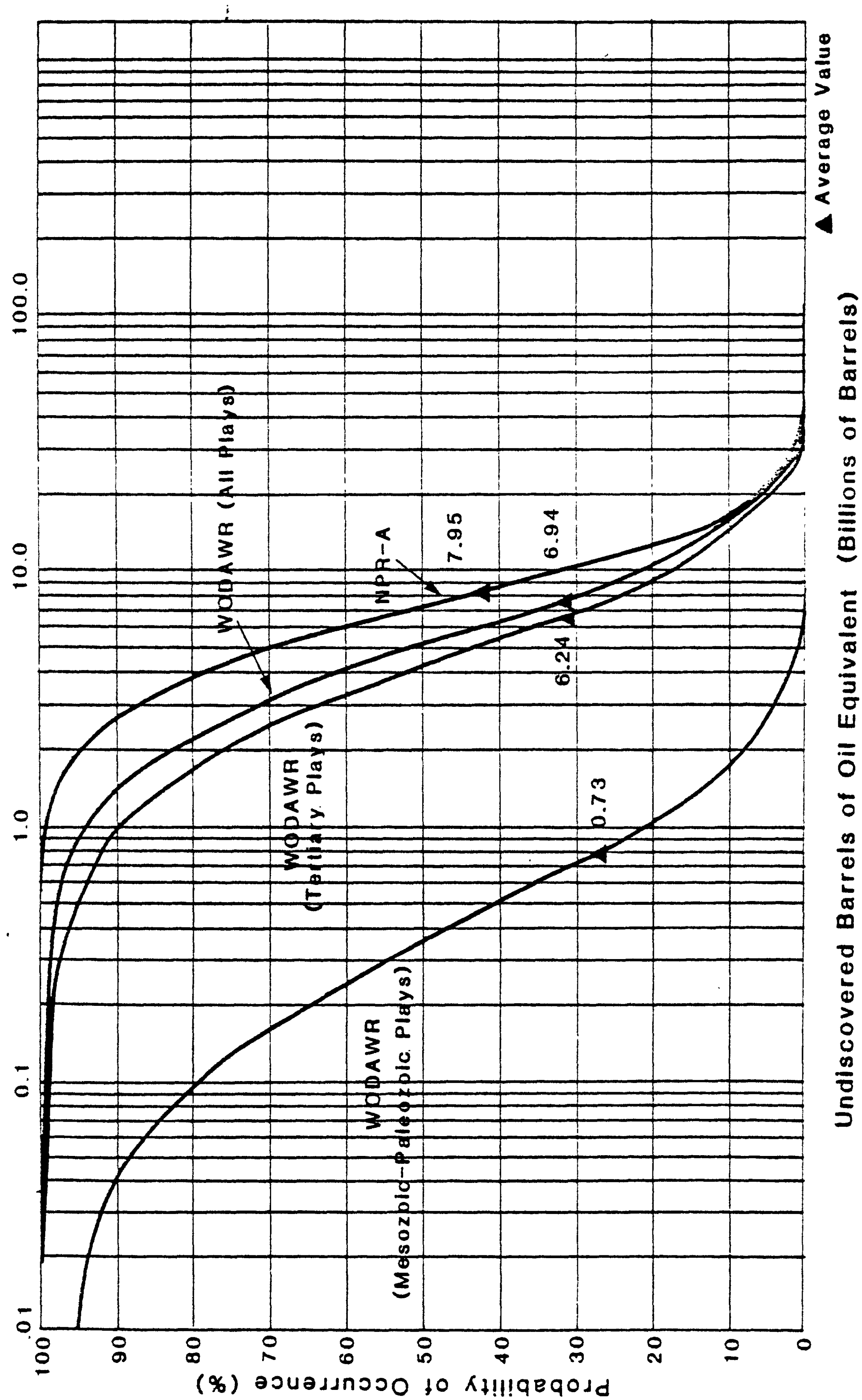
Figure 11 gives the companion set of curves for estimates of undiscovered gas derived from the play analysis. Figure 12 combines both the undiscovered oil and the undiscovered gas into a single, barrels of oil equivalent, distribution. This is accomplished by converting the gas into equivalent barrels of oil on an energy basis. Equivalency used for these conversions is 5600 cubic feet of gas equals one barrel of oil equivalent gas. The barrels of oil of equivalent gas resources then are aggregated with the oil resources.

Figure 13 shows the companion probability distributions for the oil and gas pools sizes which were generated in the resource model. Pool size is



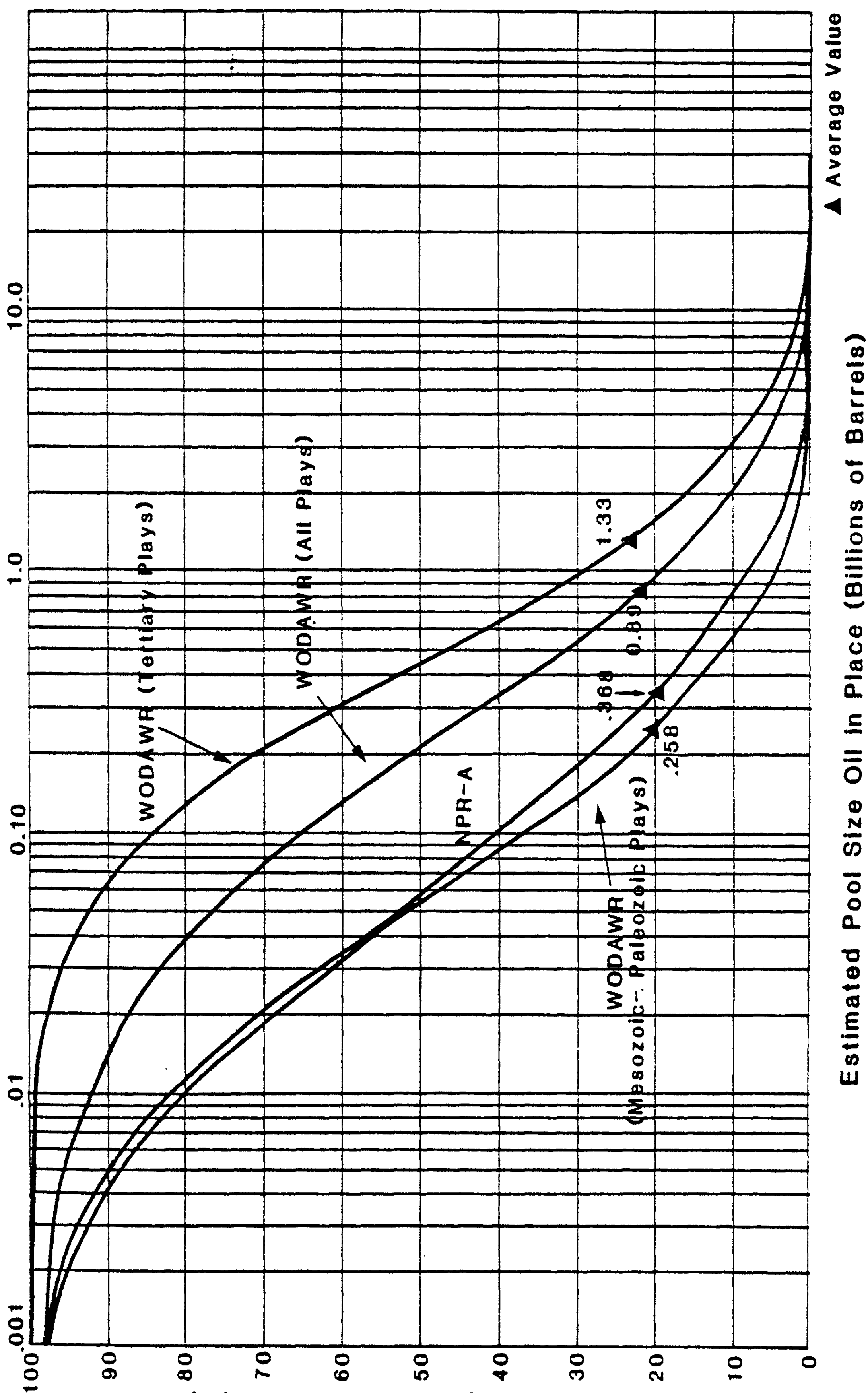
Probability of Occurrence (%)
100
90
80
70
60
50
40
30
20
10
0
.01
0.1
1.0
10.0
100.0
NPR-A (Total)
WODAWR (Total)
WODAWR (Tertiary Plays)
WODAWR (Mesozoic-Paleozoic Plays)
11.03
11.90
9.80
2.2
Undiscovered Gas in Place (Trillions of Cubic Feet)
▲ Average Value

Figure 12



Probability of Occurrence (%)
Undiscovered Barrels of Oil Equivalent (Billions of Barrels)
▲ Average Value
WODAWR (All Plays)
NPR-A
WODAWR (Tertiary Plays)
WODAWR (Mesozoic-Paleozoic Plays)
7.95
6.94
6.24
0.73
.01
0.1
1.0
10.0
100.0
100
90
80
70
60
50
40
30
20
10
0

Figure 13



Probability of Occurrence (%)
100
90
80
70
60
50
40
30
20
10
0
.001
.01
0.10
1.0
10.0
Estimated Pool Size Oil in Place (Billions of Barrels)
▲ Average Value
WODAWR (Tertiary Plays)
WODAWR (All Plays)
NPR-A
WODAWR (Mesozoic - Paleozoic Plays)
1.33
0.89
.368
.258

calculated for both oil and gas pools in terms of the volume of oil they would contain. These curves express at a given probability level that a discovered field will be equal to or greater than the size read from the curve at that probability level. It should be noted that in order to convert pools by size in terms of volumes of oil to volumes of gas one would have to know the reservoir temperature and pressure because gas is highly compressible; these estimates and calculations have not been made for this report.

DISCUSSION OF RESULTS

Play Analysis

Table 1 summarizes the information presented in figures 10-13 and for the total resource distribution for the Wildlife Range and NPRA. As shown in the Table, the total resource estimates for these two areas are quite similar; even though NPRA in-place resources are somewhat larger, this is offset by the fact that NPRA is considerably larger in area than the Wildlife Range. The major difference shown in Table 1 between these two areas is in the probability distributions for the estimated pool sizes which result from the play analysis resource-appraisal processes. As appraised, the mean pool size estimated for the Wildlife Range is 2.4 times as large as the mean pool size estimated for NPRA. The larger the pool size, in general, the greater the chance for the discovery of economic accumulations of both oil and gas. The interdependency noted before for the Mesozoic-Paleozoic plays might tend to make oil fields (vertically stacked plays) in NPRA larger than the aggregate of the individual pools assessed, but this same dependency for these plays may also exist within the Wildlife Range. However, only a small portion of the Wildlife Range's total resources is estimated for the Mesozoic-Paleozoic plays; therefore increases in the discovered field sizes over what was assessed for pool sizes might not be as great for the Wildlife Range as it is for NPRA. On the other hand, it is possible that there will also be some interdependency between some of the Tertiary plays in the Wildlife Range, which would tend to have the same effect of increasing the discovered field sizes. Given that the dependency issue probably affects both NPRA and WODAWR approximately equally, it is assumed that the pool size variant between the two areas as shown in figure 13 is real.

Table I

Distribution Values of the Estimated Oil and Gas Resources In Place, Barrels of Oil Equivalents In Place and Estimated Pool Sizes by the Play Analysis Method.

	95%*	5%*	Mean
Oil Resources (Billions of Barrels)			
WODAWR	.16	17.03	4.85
NPRA	.82	15.42	5.96
Gas Resources (Trillions of Cubic feet)			
WODAWR	1.44	33.93	11.9
NPRA	2.41	27.20	11.3
Barrels of Oil Equivalents (Billions of Barrels)**			
WODAWR	0.86	20.53	6.94
NPRA	1.90	18.42	7.95
Pool Size (Billions of Barrels)			
WODAWR	.006	3.81	0.89
NPRA	.002	1.73	0.37

* Probability that the quantity is at least the given value

** Barrels of Oil Equivalents were calculated by a computer/Monte Carlo technique and cannot be obtained by converting the estimated gas in place to energy equivalents in oil and adding the resulting value to the estimated oil in place.

Direct Assessment

After completion of the play analysis assessment a separate (Resource Appraisal Group-Type) subjective assessment was completed by the assessment committee for comparative purposes (see Miller and others, 1975). In making the subjective RAG-type assessment, all of the known geology is reviewed as well as the results from different methods of calculating potential hydrocarbon resources. Thus, the RAG assessment procedure allows the individuals on the assessment committee to use all available methods and in this case to also incorporate the results of the play analysis methodology into the subjective assessment. The analog data and the procedure used in the RAG method were developed for basin-wide appraisals. It is difficult to apply these techniques to small portions of a basin and the uncertainly for small areas is large. Based on the results, however, it would appear that the RAG estimates for WODAWR were strongly influenced by the results from the OMPRA play type appraisal. However the wide range of the individual assessments indicate a high level of uncertainty. The results of the RAG appraisal and play appraisal are quite similar with the exception of the higher value for the RAG appraisal for the 95% oil estimate. Volumetric yields calculated from the appraisals and the small sediment volumes in the Range, are very high. This does not necessarily imply high basinwide yields, but may be interpreted to mean that the WODAWR coastal plain is rated by the appraisal committee as a high potential area within the Northern Alaska-Beaufort Sea basin. Table 2 contains the average values from the RAG assessment and the ranges of the individual estimates:

Table 2. Undiscovered in-place resources assessed by the RAG method*

	95%	5%	Mode	Mean**
Oil (in billions of barrels)				
Average Estimate	.8	17.6	5.6	5.8-8.5
Range of Individual Estimates	.1-2	10-20	1-10	
Gas (in trillions of cubic feet)				
Average Estimate	1.4	28.1	9.5	9.5-13.9
Range of Individual Estimates	.7-3	20-35	5-20	

* All numbers are rounded to nearest 0.1.

** The RAG methodology includes estimates of 95%, 5%, and mode values. The mean values shown here are calculated by fitting a lognormal distribution to two of the estimated values. The low mean values shown are from the curve fit to the 95% and mode estimates, and the high mean values are from the curve fit to the 5% and mode estimates. Since the original distributions were not lognormal, the mean values from the two curve fits are quite different and give only an approximate range for the mean.

Recovery of Oil and Gas

Actual estimates of the recovery of oil and gas were not made as part of this appraisal. In order to develop estimates of recovery for the Wildlife Range which are comparable with those for NPRA, for example, the production and economic models developed in the OMPRA 105(b) study for NPRA should be run for the Wildlife Range. The estimates for oil and gas recovery for NPRA have been published, however, and they provide a basis for a discussion of the recovery of oil and gas for the Wildlife Range.

In NPRA (U.S. Department of the Interior, 1979) the 105(b) model study shows that approximately 26% of the oil in place and 27% of the gas in place at the mean values estimated were recoverable under their base case conditions for commodity prices, exploration expenditures, transportation costs, development costs, etc. In that model run, reservoir recoveries were assumed to be 35% for oil and 75% for gas. The difference between these two sets of recovery factors is a function of economics. Because the calculations are so complex, the committees discussed some of these problems but did not speculate on what the final results from a computer analysis might be. Factors discussed were the gravity of oils, reservoir rock quality and continuity, transportation distances, pipeline costs, and field size. Some of these factors might tend to reduce overall recoveries whereas others would tend toward increasing them. It is not clear at this time, given the data available, that the reservoir recovery factors will be the same for the Wildlife Range as they are in NPRA. The writers of this report believe that overall recoveries in the Wildlife Range could be higher because of the larger estimated pool sizes and shorter transportation distances to the Trans Alaskan Pipeline System from the Wildlife Range as compared to NPRA. A production and economic model study would have to be undertaken to analyze this problem.

CONCLUSIONS

All of the petroleum potential of the Wildlife Range is thought to be in the coastal plain portion, an area comprising 27% of the total Range. This coastal plain area lies on the intersection of several major geologic trends and has characteristics of both the Prudhoe Bay and Mackenzie Delta petroleum provinces.

The absence of subsurface data and the need to project geologic interpretations and information into the area of the Wildlife Range and to apply analogs made assessment more difficult. The effect was to increase uncertainty and the range of estimated resources. The problems associated with application of the play method in a frontier region such as this must be recognized but are not considered to significantly distort nor invalidate the assessment. The bulk of the oil and gas resources are thought to occur in Tertiary plays in the Wildlife Range which do not occur in NPRA.

This assessment using the play method represents the best effort by a Survey team of geologists currently available within the time that was available for the study. Improved confidence in hydrocarbon resource estimates of the Wildlife Range will come as new and additional data are compiled for the area.

Comparison of the results of the play appraisals of the Wildlife Range with NPRA, together with a comparison of the size of the two areas, shows the Wildlife Range to have a larger probable potential resource per square mile than that of NPRA. The estimated oil per square mile in the Wildlife Range may be nearly 8 times that in NPRA when the average values are compared, and almost 6 times that in NPRA when the 50th fractiles are compared. The plays in Tertiary rocks, which are absent in NPRA and may contain most of the estimated resource in the Wildlife Range, are the main source of these differences in resource assessments.

REFERENCES

Armstsrong, A. K., and Mamet, B. L., 1975, Carboniferous biostratigraphy, northeastern Brooks Range, Arctic Alaska: U.S. Geol. Survey Prof. Paper 884, 29 p.

Bird, K. J., 1978, Generalized isopach map of the Endicott Group eastern North Slope petroleum province, Alaska: U.S. Geol. Survey Misc. Field Studies Map MF-928T.

Brosge, W. P., Dutro, J. T., Jr., Mangus, M. D., and Reiser, H. J., 1962, Paleozoic sequence in eastern Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin 46, no. 12, p. 2174-2198.

Brosge, W. P., and Tailleur, I. L., 1971, Northern Alaska petroleum province: in Cram, I. H., ed., Future petroleum provinces of the United States - their geology and potential: American Association of Petroleum Geologists Memoir 15, p. 68-99.

Canada Department of Energy, Mines and Resources, 1977, Oil and natural gas resource of Canada, 1976: Ottawa, Report EP77-1, 76 p.

Carter, C., and Laufeld, S., 1975, Ordovician and Silurian fossils in well cores from North Slope of Alaska: American Association of Petroleum Geologists Bulletin, v. 59, no. 3, p. 457-464.

Detterman, R. L., 1970, Analysis of Shublik Formation rocks from Mt. Michelson quadrangle, Alaska: U.S. Geol. Survey Open File Report OF 404, 1 p., 1 table, 2 figures.

__________, 1974, Fence diagram showing lithologic facies of the Saddlerochit Formation (Permian and Lower Triassic), northeastern Alaska: U.S. Geol. Survey Misc. Field Studies Map. MF-584, 1 sheet.

Detterman, R. L., Reiser, H. N., Brosge, W. P., and Dutro, J. T., Jr., 1975, Post-Carboniferous stratigraphy, northeastern Alaska: U.S. Geol. Survey Prof. Paper 886, 46 p.

Dutro, J. T., Jr., 1970, Pre-Carboniferous carbonate rocks, northeastern Alaska: in Adkison, W. L., and Brosge, M. M. eds. Proceedings of the geological seminar on the North Slope of Alaska, Pacific Section, Amer. Assoc. of Petroleum Geologists, Los Angeles. p. M1-M8.

Grantz, Arthur, and Mull, C. G., 1978, Preliminary analysis of the petroleum potential of the Arctic National Wildlife Range, Alaska: U.S. Geol. Survey Open-File Report 78-489, 21 p.

Grantz, A., Eittreim, S., and Dinter, D. A., 1979, Geology and tectonic development of the continental margin north of Alaska: Tectonophysics, v. 59, p. 263-291.

Jones. H. P., and Speers, R. G., 1976, Permo-Triassic reservoirs of Prudhoe Bay Field, North Slope, Alaska: in Braunstein, J., ed., North Ameircan oil and gas fields: Amer. Assoc. Petroleum Geologists Memoir 24, p. 23-50.

Kososki, B. A., Reiser, H. N., Cavit, C. D., and Detterman, R. L., 1978, A gravity study of the northern part of the Arctic National Wildlife Range, Alaska: U.S. Geol. Survey Bulletin 1440, 21 p., 3 maps 1:250,000 scale.

Lerand, M., 1973, Beaufort Sea: in McCrossan, R. G., ed., The future petroleum provinces of Canada - their geology and potential: Canadian Society of Petroleum Geologists Memoir 1, p. 315-386.

Miller, B. M., Thompsen, H. L., Dolton, G. L., Coury A. B., Hendricks, T. A., Lennartz, F. E., Powers, R. B., Sable, E. G., and Varnes, K. L., 1975, Geological estimates of undiscovered recoverable oil and gas resosurces in the United States, U.S. Geol. Survey Circular 725, 78 p.

Morgridge, D. L., and Smith, W. B., 1972, Geology and discovery of Prudhoe Bay field, eastern Arctic Slope, Alaska: in King, R. E., ed., Stratigraphic oil and gas fields - classification, exploration methods, and case histories: Amer. Assoc. Petroleum Geologists Memoir 16, p. 489-501.

Norris, D. K., 1978, Geological maps of Yukon Territory and Northwest Territories: Geological Survey of Canada Open-File Report OF -- 499, 6 sheets, 1:250,000 scale.

Palmer, I. F., Jr., Bolm, J. G., Maxey, L. R. and Lyle, W. M., 1979, Petroleum source rock and reservoir quality data from outcrop samples, onshore North Slope of Alaska east of Prudhoe Bay: U.S. Geol. Survey Open-File Report OF -- 79 - 1634, 52 p., 14 plates, 6 tables.

Pessel, G. H., Levorsen, J. A., Tailleur, I. L., 1978, Generalized isopach and net sand maps of Lower Cretaceous sands Eastern North Slope petroleum province, Alaska: U.S. Geological Survey Misc. Field Studies Map MF-928J.

Reed, B. L., 1968, Geology of the Lake Peters area, northeastern Brooks Range, Alaska: U.S. Geol. Survey Bull. 1236, 132 p.

Reiser, H. N., 1970, Northeastern Brooks Range -- a surface expression of the Prudhoe Bay section: In Adkison, W. L. and Brosge, M. M., eds., Proceedings of the geological seminar on the North Slope of Alaska, Pacific Section, Amer. Assoc. Petroleum Geologists, Los Angeles, p. K1-K14.

Reiser, H. N., Brosge, W. P., Detterman, R. L. and Dutro, J. T., Jr., 1978, Geologic map of the Demarcation Point quadrangle, Alaska: U.S. Geol. Survey Open-File Report OF - 78 - 526, 1 sheet, 1:250,000 scale.

______, 1971, Preliminary geologic map, Mt. Michelson quadrangle, Alaska: U.S. Geological Survey Open-File Report OF 479, 2 sheets, 1:200,000 scale.

Rickwood, F. R., 1970, The Prudhoe Bay Field, in W. L. Adkison and M. M. Brosge, eds., Proceedings of the Geological Seminar on the North Slope of Alaska, Pacific Section, Amer. Assoc. of Petroleum Geologists, Los Angeles, p. L1-L11.

Roy, K. J., Procter, R. N., and McCrossan, R. G., 1975, Hydrocarbon assessment using subjective probability, in Davis, J. C. and others, conveners, Probability methods in oil exploration: American Association of Petroleum Geologists Research Symposium, Stanford University, Notes, p. 56-60.

Seifert, W. K., Moldowan, J. M., and Jones, R. W., 1979, Application of biological marker chemistry to petroleum exploration. Special Paper SP8, 10th World Petroleum Congress, Bucharest, p. 425-440.

Tailleur, I. L., Pessel, G. H., Engwight, S. E., 1978, Subcrop map at Lower Cretaceous unconformity, and maps of Jurassic and Lower Cretaceous seismic horizons eastern North Slope petroleum province, Alaska: U.S. Geological Survey Misc. Field Studies Map MF-928 I.

U.S. Department of the Interior, 1979, Final report of the 105(b) economic and policy analysis: Prepared by the U.S. Dept. of the Interior, Office of Minerals Policy and Research Analysis, U.S. Government Printing Office, 145 p.

White, L. P., 1979, A play approach to hydrocarbon resource assessment and evaluation: in Proceedings of the Conference on the economics of exploration for energy resource: New York University, May 17-18, 1979 (in press).

Young, F. G., Myhr, D. W. and Yorath, C. J., 1976, Geology of the Beaufort-Mackenzie basin: U.S. Geol. Survey of Canada Paper 76-11, 65 pp.

APPENDIX I

Play descriptions, data forms, and illustrations

DEMARCATION PLAY

The Demarcation play is in structurally and stratigraphically trapped multiple sandstone reservoirs of Eocene to Pliocene age. It includes the entire interval of fluvial and marine sandstone, conglomerate, siltstone and shale above the "mid-Eocene" unconformity. Although poorly exposed, this interval is about 5,000 feet thick in the east, according to the offshore seismic evidence, and may be as much as 7,000 feet thick in the west (in Exxon Alaska St. A-1). The rocks extend offshore to the north and east; the southern boundary of the play area is the south limit of their outcrop.

Reservoir rocks are poorly consolidated sandstone and conglomerate which occur in units as much as 75 feet thick and comprise one-third of the exposed section of Marsh Anticline (Detterman and others, 1975, figure 13). Porosities of 10% to 26% are known at some localities (fig. 3).

Geochemical data indicate that these Eocene to Pliocene rocks are carbonaceous, but immature (Palmer and others, 1979). However, oil seeps in these rocks at Manning Point and Angun Point, and a reported offshore gas seep near Demarcation Point indicate that they are in communication with mature source rocks and also may contain biogenic gas.

Postulated traps are small structural traps, or small combination traps where individual sands pinch out; a few large structure such as Marsh Anticline and the similar anticlines observed offshore; and a possible large stratigraphic trap due to truncation of the lower part of the interval by the Miocene or Pliocene beds (A. Grantz, personal communication). No four-way closures are known. These shallow rocks are breached in Marsh Anticline and are probably partly breached in other structures. This interval is said to be non-prospective to the east in offshore Canada (R. Proctor, personal communication.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Demarcation*

DATE EVALUATED: *5/15/80* REVISED: *6/2/80*

	ATTRIBUTE		PROB. OF FAVORABLE							COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)		1							
	TIMING (T)		1							
	MIGRATION (M)		1							
	POTENTIAL RESERVOIR FACIES (R)		1							
	PLAY PROBABILITY (SxTxMxR=MP)		1							seeps
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)		0.1							
	EFFECTIVE POROSITY (≥3%) (P)		1							
	HYDROCARBON ACCUMULATION (C)		0.8							
	PROSPECT PROBABILITY (TMxPxC=CP)		0.08							
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	1							
		CARBONATE	-							
	HYDROCARBON MIX	GAS	.5							
		OIL	.5							
	ATTRIBUTE / FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)		100	95	75	50	25	5	0	
	AREA OF CLOSURE ($x10^3$ ACRES)		.6	1	3	7	10	45	100	
	RESERVOIR THICKNESS (FT)		400	800	1000	1500	2000	3500	5000	
	EFFECTIVE POROSITY (%)		10	14	18	20	25	30	40	
	TRAP FILL (%)		1	2	4	5	6	10	30	
	RESERVOIR DEPTH ($x10^3$ FT)		.1	uniform distr. between					10	
	NUMBER OF DRILLABLE PROSPECTS		8	10	15	20	25	30	35	
PROVED RESERVES ($x10^6$ BBLS; TCF)										

DEMARCATION GAS FRACTION = .5

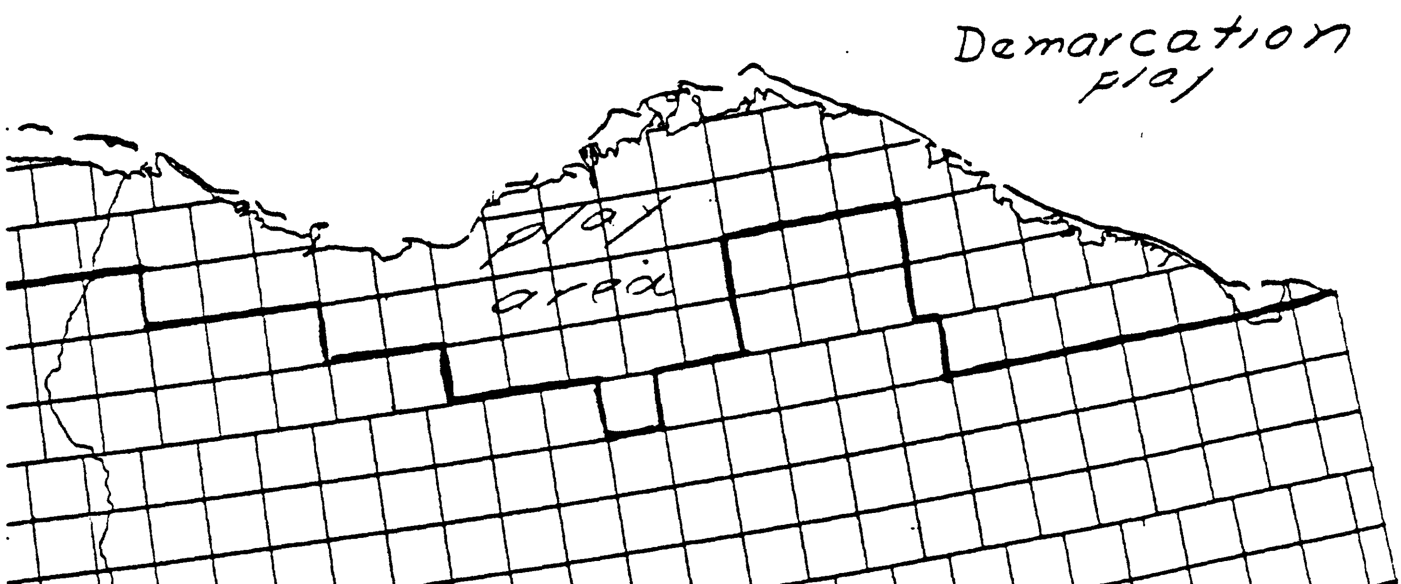
CONDITIONAL
<---------------RESOURCES IN PLACE--------------->

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	18.33	15.32
.50	76.05	315.09	288.22
.25	875.65	1268.37	1212.59
.05	4798.63	5531.23	5287.26
0.00	31255.28	74038.99	31760.43

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
985.71	1243.63	1203.89

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	5.739
.95	47.693
.75	180.567
.50	448.999
.25	1178.851
.05	4817.764
0.00	47983.525

AVERAGE POOL SIZE (MILLIONS)
1239.09



FLAXMAN PLAY

The Flaxman play is in stratigraphically or structurally trapped multiple sandstone reservoirs of Eocene and Paleocene age. It comprises the interval of Tertiary marine and fluvial sandstone, conglomerate and shale beneath the "mid-Eocene" unconformity. It also includes the undifferentiated Paleocene or Upper Cretaceous fluvial rocks and the tuffaceous marine shale that marks the base of the Upper Cretaceous. The Tertiary part of the interval is at least 1,000 feet thick and may be as much as 6,000 feet thick; the Upper Cretaceous shale is about 500 feet thick (Detterman and others, 1975).

The play is confined to the area near the Canning River that surrounds the postulated east-plunging nose of the Barrow Arch and includes a large Tertiary basin across the nose of the Arch that is inferred from gravity data (fig. 5). The eastern boundary is at a saddle in this basin

Reservoir rocks are poorly consolidated sandstone and conglomerate that occur in units as much as 75 feet thick and comprise about 30% of the exposed sections (Detterman and others, 1975). Clean porous sand beds 50 feet thick and porosities as great as 23% have been noted; the estimated average porosity is 17% (in Exxon Alaska St. A-1).

Oil-saturated sands crop out near the Paleocene-Upper Cretaceous contact, and the oil in the Exxon Alaska State A1 well on Flaxman Island is believed to be in the play interval. Geochemical data indicate that the Tertiary rocks are generally a poor source. Although they contain up to 2% organic carbon, they are only partly mature and the kerogen is generally herbaceous. The Upper Cretaceous shale at the base of the interval is a good to excellent source rock, containing 5% to 12% organic carbon, rich in amorphous kerogen and generally mature. The underlying Lower Cretaceous shale is an excellent source rock (Palmer and others, 1979).

Postulated traps are stratigraphic traps against the Barrow Arch and at the south flank of the Tertiary basin, and a possible large structural trap on trend with Marsh Anticline. No four-way closure is known.

2

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Flaxman*

DATE EVALUATED: *5/15/80* REVISED: *6/2/80*

	ATTRIBUTE	PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)	1	
	TIMING (T)	1	
	MIGRATION (M)	1	
	POTENTIAL RESERVOIR FACIES (R)	1	
	PLAY PROBABILITY (SxTxMxR=MP)	1	Oil in Exxon Flaxman Id Alaska State A-1
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)	.5	
	EFFECTIVE POROSITY (≥3%) (P)	1	
	HYDROCARBON ACCUMULATION (C)	.9	
	PROSPECT PROBABILITY (TMxPxC=CP)	.45	
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY — SAND	1	
	RESERVOIR LITHOLOGY — CARBONATE	—	
	HYDROCARBON MIX — GAS	.2	
	HYDROCARBON MIX — OIL	.8	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0
AREA OF CLOSURE ($x10^3$ ACRES)	.6	2	3	7	15	50	100
RESERVOIR THICKNESS (FT)	100	200	400	600	700	800	1000
EFFECTIVE POROSITY (%)	10	12	15	17	20	25	30
TRAP FILL (%)	1	5	15	20	30	55	75
RESERVOIR DEPTH ($x10^3$ FT)	.1	—	—	10	—	—	20
NUMBER OF DRILLABLE PROSPECTS	2	3	4	6	8	10	12

PROVED RESERVES ($x10^6$ BBLS; TCF)

FLAXMAN GAS FRACTION = .

CONDITIONAL
<----------------RESOURCES IN PLACE---------------

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLION
1.00	0.00	0.00	0.
.95	0.00	0.00	0.
.75	78.40	456.78	366.
.50	696.92	1728.21	1289.
.25	2275.86	4745.04	3374.
.05	9240.74	15552.35	11259.
0.00	49497.13	81994.39	53378.

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE B (MILLION
2198.92	3912.65	2885.

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	1.819
.95	35.493
.75	144.273
.50	388.116
.25	1091.395
.05	5173.716
0.00	42025.503

AVERAGE POOL SIZE (MILLIONS)
1208.69

Flaxman play
and
Sadlerochit play

SABBATH PLAY

The Sabbath play is in structurally and stratigraphically trapped multiple sandstone reservoirs of Eocene, Paleocene, and possibly Late Cretaceous age. It comprises the interval of dominantly fluvial Tertiary sandstone, conglomerate and shale beneath the "mid-Eocene" unconformity, and, like the Flaxman play, it also includes all the underlying Paleocene or Upper Cretaceous fluvial and marine rocks down to the base of the tuffaceous Upper Cretaceous shale.

The interval is more than 11,000 feet thick where exposed in the south-central part of the play area (Detterman and others, 1975, figs. 9 and 10). It includes at least 5,000 feet of Tertiary fluvial deposits and the underlying 2,000 feet of shallow marine deposits and 4,000 feet of turbidites(?) of Paleocene or Late Cretaceous age. The proportion of marine deposits probably increases northward.

The play area extends north and east to the sea except in an area that has been outlined around a large gravity high where older Lower Cretaceous and Jurassic rocks are locally exposed. The south boundary is at the outcrop limit of Upper Cretaceous rocks.

Reservoir rocks are dirty, and probably lenticular sandstone and conglomerate that form about 30% of the exposed section. Porosity of outcrops in the southern part of the area is 3% to 5% (Palmer and others, 1970) but is expected to increase northward.

An oil seep occurs within the play area, and, immediately offshore, a ships captain has reported a gas seep. As in the Flaxman play the Tertiary rocks are generally poor source rocks because of immaturity, organic carbon contents of less than 2% and high proportion of herbaceous kerogen. The organic rich shale at the base of the Upper Cretaceous is a good, probably oil-prone, source rock, and the underlying Lower Cretaceous shale is an excellent source rock (Palmer and others, 1979; Mull and Claypool, unpublished data).

Postulated traps are small structural and combination traps, and some large structural traps like Marsh Anticline, which is in the western part of the play area. No four-way closure is known.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ____________ PLAY NAME: Sabbath

DATE EVALUATED: 5/16/80 REVISED: 6/2/80

	ATTRIBUTE	PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)	1	
	TIMING (T)	1	
	MIGRATION (M)	1	
	POTENTIAL RESERVOIR FACIES (R)	1	
	PLAY PROBABILITY (SxTxMxR=MP)	1	seeps
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)	.2	
	EFFECTIVE POROSITY (≥3%) (P)	1	
	HYDROCARBON ACCUMULATION (C)	.8	
	PROSPECT PROBABILITY (TMxPxC=CP)	.16	

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	1	
		CARBONATE	—	
	HYDROCARBON MIX	GAS	.4	
		OIL	.6	

FRACTILES / ATTRIBUTE (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0	COMMENTS
AREA OF CLOSURE ($x10^3$ ACRES)	.6	1	3	7	10	40	80	
RESERVOIR THICKNESS (FT)	1000	1100	1500	2000	3000	3800	4000	
EFFECTIVE POROSITY (%)	3	4	8	12	15	20	30	
TRAP FILL (%)	1	3	9	12	18	32	60	
RESERVOIR DEPTH ($x10^3$ FT)	.1	1	6	12	18	22	25	
NUMBER OF DRILLABLE PROSPECTS	3	4	7	10	15	20	25	
PROVED RESERVES ($x10^6$ BBLS; TCF)								

SABBATH GAS FRACTION = .4

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.0
.95	0.00	0.00	0.0
.75	0.00	63.08	29.2
.50	0.00	1223.69	568.4
.25	867.64	5172.11	2203.6
.05	6508.85	20671.21	8733.5
0.00	90724.26	125369.97	93269.8

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
1339.72	4648.12	2155.1

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	2.724
.95	34.690
.75	170.950
.50	488.363
.25	1444.645
.05	6487.338
0.00	77859.250

AVERAGE POOL SIZE (MILLIONS)
1594.87

Flaxman play and Sabbath play

KEMIK PLAY

The Kemik play is in stratigraphically and structurally trapped linear sandstone bodies of Early Cretaceous age deposited at the regional Lower Cretaceous unconformity. It comprises the Kemik Sandstone, which occurs adjacent to the Brooks Range and was probably deposited as one or more long sand bars derived from northern or southern sources. It may also include similar sandstones derived from local sources to the north, like the Kuparuk River sandstone farther west on the Barrow Arch (Pessel and others, 1978). The play interval includes the 300 to 900 foot thick Lower Cretaceous pebble shale within which the sandstone occurs. The play area is the entire area north of the mountain front, although the Kemik Sandstone has not been observed in the eastern half of the area, except within the mountains (Reiser and others, 1978).

Reservoir rocks are fine-grained sandstone, generally less than 100 feet thick, with low porosity in the outcrop, but productive in the subsurface at Prudhoe Bay. The one bar-like body exposed adjacent to the play area is about 4 miles wide and 40 miles long (C. Mull, personal communication).

Geochemical data show that the Lower Cretaceous pebble shale, which encloses the Kemik Sandstone, is an excellent, oil-prone source rock containing 3% to 4% organic carbon and generally rich in amorphous kerogen. The underlying Jurassic Kingak Shale and the overlying Upper Cretaceous shale are good source rocks (Palmer and others, 1979; Mull and Claypool, unpublished data).

Postulated traps are small structural traps, many small stratigraphic and combination traps at pinch-outs of individual bars, and a possible large stratigraphic trap comprising a single large bar.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ____________ PLAY NAME: Kemik

DATE EVALUATED: 5/16/80 REVISED: 6/2/80

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)		1	
	TIMING (T)		1	
	MIGRATION (M)		1	
	POTENTIAL RESERVOIR FACIES (R)		1	
	PLAY PROBABILITY (SxTxMxR=MP)		1	
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TH)		0.1	
	EFFECTIVE POROSITY (≥3%) (P)		1.0	
	HYDROCARBON ACCUMULATION (C)		0 9	
	PROSPECT PROBABILITY (THxPxC=CP)		0.09	
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	1	
		CARBONATE	—	
	HYDROCARBON MIX	GAS	.2	
		OIL	.8	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0	COMMENTS
AREA OF CLOSURE ($x10^3$ ACRES)	.6	1	3	5	7	25	160	
RESERVOIR THICKNESS (FT)	5	10	50	75	85	100	200	
EFFECTIVE POROSITY (%)	3	5	8	10	12	17	25	
TRAP FILL (%)	1	7	19	30	45	75	100	
RESERVOIR DEPTH ($x10^3$ FT)	.1	1	6	12	18	22	25	
NUMBER OF DRILLABLE PROSPECTS	8	10	15	20	25	30	35	

PROVED RESERVES ($x10^6$ BBLS; TCF)

KEMIK GAS FRACTION = .20

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	4.54	3.69
.50	8.84	58.70	37.79
.25	67.59	209.85	126.65
.05	367.39	962.92	510.64
0.00	9439.73	30488.72	9555.31

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
92.54	250.76	136.54

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	.070
.95	1.575
.75	8.426
.50	24.058
.25	63.078
.05	314.892
0.00	13842.466

AVERAGE POOL SIZE (MILLIONS)
88.12

SAG RIVER-KAREN CREEK-SHUBLIK PLAY

This play is in structurally and possibly stratigraphically trapped limestone of Triassic age and marine sandstone of Triassic or Jurassic age. It comprises the formations in the interval between the Jurassic Kingak Shale and the Lower Triassic Ivishak Formation. In the outcrop these formations are the Upper Triassic Shublik Formation and the overlying Upper Triassic(?) Karen Creek Sandstone (Detterman and others, 1975); in the subsurface on the Barrow Arch to the northwest they are the Shublik Formation and the Jurassic Sag River Sandstone (Jones and Spears, 1976). The interval is about 500 feet thick in the outcrops south of most of the play area. However, because of truncation by the Lower Cretaceous unconformity, it is missing along 25 miles of the southwestern play boundary (Reiser and others, 1971), is less than 200 feet thick immediately west of the play area, (Exxon Canning River B-1), and is missing on the Barrow Arch immediately northwest of the play area (Tailleur and others, 1978).

The southern play boundary is generally at the outcrop of the Triassic rocks, but jogs 6 miles north of the outcrop area in which they are missing through Lower Cretaceous truncation. The northern boundary is the sea, except on the lower Canning River where the Triassic rocks are believed to be missing on the east plunging nose of the Barrow Arch that has been inferred from gravity data (Tailleur and others, 1978). Depending on the location of any additional truncation by the Lower Cretaceous, and on the location of a possible truncation by the Jurassic, the formations in this interval may be absent over a large part of the play area.

Reservoir rocks are as much as 300 feet of limestone and calcareous siltstone in the Shublik Formation and as much as 200 feet of fine-grained glauconitic sandstone in the eastward-thickening Karen Creek Sandstone

(Detterman and others, 1975). The glauconitic Sag River Sandstone, if present, may be as much as 90 feet thick, as in the Prudhoe area. Data from the Prudhoe area show porosities of 5% to 30% in the Shublik and 10% to 25% in the Sag River, which may be caused by the Lower Cretaceous unconformity (Jones and Speers, 1976). Outcropping Karen Creek Sandstone is cemented by calcite and siderite (Reed, 1968) and probably has low porosity.

Gas occurs in the Shublik in the nearby Kavik gas field. Geochemical data indicate that the Shublik is a good source rock, containing 0.5% to 2% organic carbon, and mature for oil and gas. The overlying Kingak Shale is also a good source rock (Palmer and others, 1979; Mull and Claypool, unpublished data; Detterman, 1970).

Postulated traps are small structural traps, a possible large structural trap on Marsh Anticline, and possible very large stratigraphic traps if a sub-Cretaceous or sub-Jurassic truncation edge extends through the play area.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Sag River-Karen CK-Shublik*

DATE EVALUATED: *5/19/80* REVISED: ______________

ATTRIBUTE			PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)		/	
	TIMING (T)		/	
	MIGRATION (M)		/	
	POTENTIAL RESERVOIR FACIES (R)		/	
	PLAY PROBABILITY (SxTxMxR=MP)		/	*Kavik gas field*
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)		.2	
	EFFECTIVE POROSITY (≥3%) (P)		.5	
	HYDROCARBON ACCUMULATION (C)		.5	
	PROSPECT PROBABILITY (TMxPxC=CP)		.05	
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	.5	
		CARBONATE	.5	
	HYDROCARBON MIX	GAS	.5	
		OIL	.5	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0
AREA OF CLOSURE ($x10^3$ ACRES)	.6	5	10	20	40	50	200
RESERVOIR THICKNESS (FT)	5	20	50	100	200	400	500
EFFECTIVE POROSITY (%)	3	4	6	8	10	12	25
TRAP FILL (%)	1	5	20	30	40	60	100
RESERVOIR DEPTH ($x10^3$ FT)	.1	2	7	14	20	25	30
NUMBER OF DRILLABLE PROSPECTS	2	3	5	7	12	20	23

PROVED RESERVES ($x10^6$ BBLS; TCF)

SAG/SHUBLIK GAS FRACTION = .50

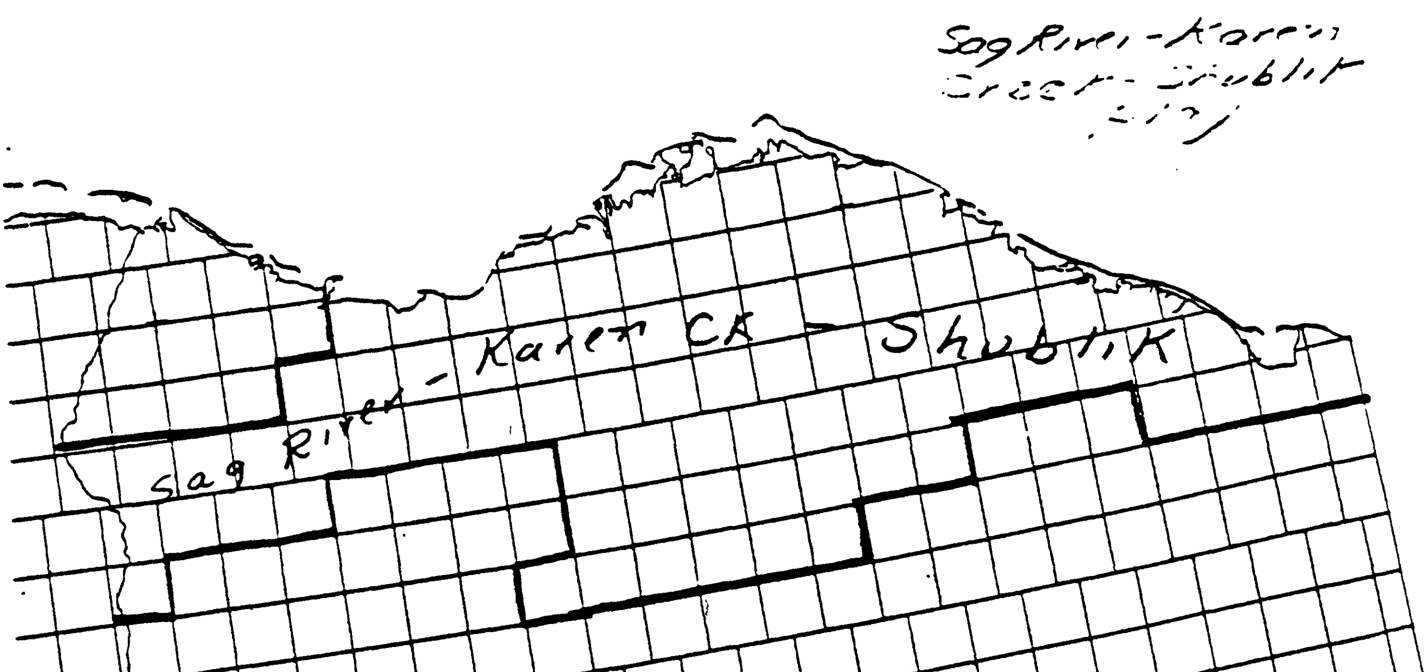
CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	88.87	30.95
.05	225.78	1533.93	520.31
0.00	16159.23	17055.80	18039.95

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
56.97	268.36	104.05

FRACTILE	POOL SIZE (100% OIL — MILLIONS OF BARRELS)
1.00	.532
.95	4.864
.75	32.740
.50	100.145
.25	312.784
.05	1205.598
0.00	16141.602

AVERAGE POOL SIZE (MILLIONS)
320.88



IVISHAK PLAY

The Ivishak Play consists of structurally or stratigraphically trapped sandstone reservoirs of the Ivishak Formation of Triassic age. The Ivishak part of the Sadlerochit Group, overlies the Echooka Formation and is overlain by the Shublik Formation. The formation is present in outcrop south of, and in the subsurface west of the play area (Detterman and others, 1975; Tailleur and others, 1978). It is absent from the postulated east-plunging nose of the Barrow Arch. The southern boundary of the play generally follows the outcrop of these rocks and the northern boundary generally extends to the sea. Two deltaic depositional lobes are suggested by outcrop studies (Detterman, 1974). Northward, in the play area, the Ivishak is expected to thin, to become more nonmarine, to increase in sandstone percentage and to increase in grain size. Occurrence of these rocks in the play area may be significantly reduced by Cretaceous or Jurassic truncation.

Reservoir rocks consist of as much as 400 feet of sandstone composed of quartz and chert grains with silica cement (Detterman and others, 1975). Porosities of only 2 to 10 percent are observed in outcrop (Palmer and others, 1979), but are expected to improve northward. At Prudhoe Bay porosity reaches 30 percent (Jones and Speers, 1976).

Gas occurs in the Ivishak in the nearby Kavik field. Geochemical data indicate that the overlying Shublik Formation is a good source rock containing 0.5% to 2% organic carbon and is mature for oil and gas. The underlying Kavik Member of the Ivishak is considered a poor source rock because of its similarity to the Kavik at Prudhoe Bay (Morgridge and Smith, 1972).

Postulated traps are small structures, a possible large structure (Marsh anticline) and possible large stratigraphic traps if a truncation edge (Cretaceous or Jurassic) extends through the area.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Ivishak*

DATE EVALUATED: *5/19/80* REVISED: *6/2/80*

	ATTRIBUTE	PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)	1	
	TIMING (T)	1	
	MIGRATION (M)	1	
	POTENTIAL RESERVOIR FACIES (R)	1	
	PLAY PROBABILITY (SxTxMxR=MP)	1	*Kavik gas field*
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)	.2	
	EFFECTIVE POROSITY (≥3%) (P)	.7	
	HYDROCARBON ACCUMULATION (C)	.5	
	PROSPECT PROBABILITY (TMxPxC=CP)	.07	

	ATTRIBUTE		100	95	75	50	25	5	0	COMMENTS
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	1							
		CARBONATE	—							
	HYDROCARBON MIX	GAS	.5							
		OIL	.5							
	FRACTILES / ATTRIBUTE	PROB. OF EQUAL TO OR GREATER THAN	100	95	75	50	25	5	0	
	AREA OF CLOSURE ($x10^3$ ACRES)		.6	5	10	20	40	50	200	
	RESERVOIR THICKNESS (FT)		5	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]	
	EFFECTIVE POROSITY (%)		3	7	13	15	18	23	30	
	TRAP FILL (%)		1	5	20	30	40	60	100	
	RESERVOIR DEPTH ($x10^3$ FT)		.1	2	7	15	20	25	30	
	NUMBER OF DRILLABLE PROSPECTS		2	3	5	7	12	20	23	
PROVED RESERVES ($x10^6$ BBLS; TCF)										

IVISHAK GAS FRACTION = .50

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

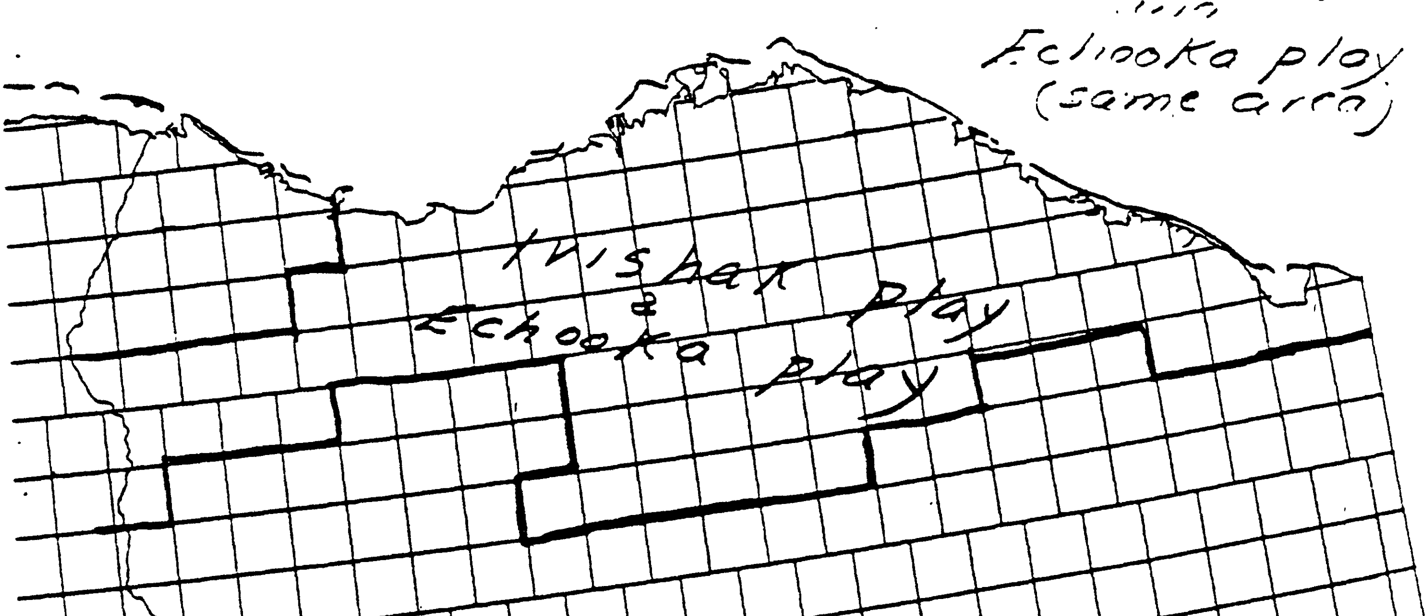
FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	619.04	180.09
.05	622.51	4311.65	1332.50
0.00	24050.44	37310.24	25855.11

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
122.84	833.36	269.06

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	.302
.95	16.620
.75	95.338
.50	269.088
.25	683.563
.05	2520.883
0.00	24050.638

AVERAGE POOL SIZE (MILLIONS)
640.86

Ivishak play
and
Echooka play
(same area)



ECHOOKA PLAY

The Echooka play consists of structurally or stratigraphically trapped sandstone reservoirs (Echooka Formation) of Permian age. The Echooka Formation (shallow marine sandstone) rests unconformably on the Lisburne Group carbonates and underlies marine shale of the Kavik Member of the Ivishak Formation (Detterman and others, 1975). Present in outcrop south of the play area and in the subsurface west of the Sadlerochit Mountains, the Echooka Formation is absent from the postulated east-plunging nose of the Barrow Arch (Tailleur and others, 1978). The southern boundary of the play is generally at the outcrop of these rocks and the northern boundary generally extends to the sea. However, the Echooka thins northward and may pinch out by depositional thinning somewhere south of the coastline. The areal distribution of the formation may also be reduced in the play area by Early Cretaceous or Jurassic truncation.

Reservoir rock consists of as much as 400 feet of glauconitic sandstone with minor silty shale interbeds. Locally, basal channel conglomerate may be present. The sandstone in outcrop is commonly silica cemented. Porosities are expected to be less than those of the Ivishak because of the presence of glauconite and other impurities (Detterman and others, 1975).

Geochemical data from the Prudhoe area (Morgridge and Smith, 1972) indicate that the overlying Kavik Member of the Ivishak and the underlying Lisburne Group are poor source rocks. They are thermally mature to overmature.

Postulated traps are small structures, a possible large structure (Marsh anticline) and possible large stratigraphic traps if a truncation edge (Cretaceous or Jurassic) extends through the area.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Echooka*

DATE EVALUATED: *5/19/80* REVISED: *6/2/80*

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE	(S)	.8	
	TIMING	(T)	1	
	MIGRATION	(M)	1	
	POTENTIAL RESERVOIR FACIES	(R)	1	
	PLAY PROBABILITY (SxTxMxR=MP)		0.8	no known occurrence
PROSPECT ATTRIBUTES	TRAP OCCURRENCE	(TM)	.2	
	EFFECTIVE POROSITY (≥3%)	(P)	.6	
	HYDROCARBON ACCUMULATION	(C)	.5	
	PROSPECT PROBABILITY (TMxPxC=CP)		.06	

HYDROCARBON VOLUME PARAMETERS			
RESERVOIR LITHOLOGY	SAND	1	
	CARBONATE	—	
HYDROCARBON MIX	GAS	.7	
	OIL	.3	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0
AREA OF CLOSURE ($\times 10^3$ ACRES)	.6	5	10	20	40	50	200
RESERVOIR THICKNESS (FT)	5	10	50	100	200	300	500
EFFECTIVE POROSITY (%)	3	5	9	12	14	18	25
TRAP FILL (%)	1	3	9	15	22	40	75
RESERVOIR DEPTH ($\times 10^3$ FT)	.1	2	7	15	20	25	30
NUMBER OF DRILLABLE PROSPECTS	2	3	5	7	12	20	25

PROVED RESERVES ($\times 10^6$ BBLS; TCF)

ECHOOKA GAS FRACTION = .70

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

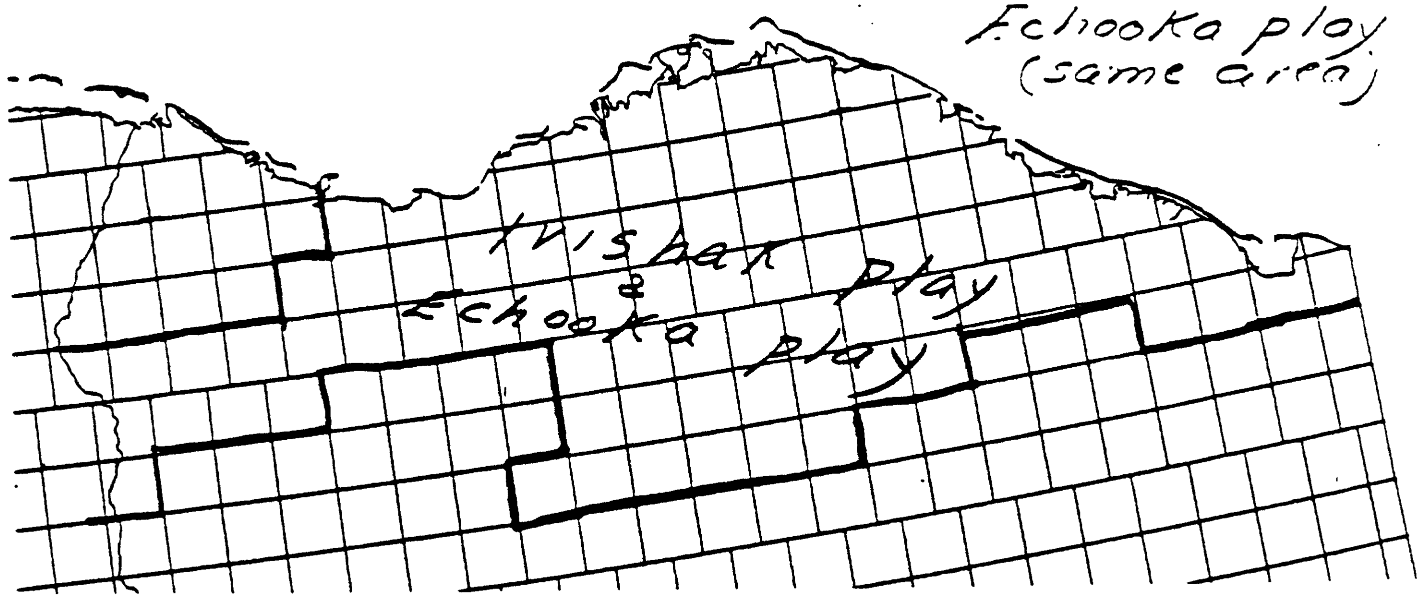
FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	99.51	23.88
.05	37.73	1675.05	415.63
0.00	4455.98	16843.86	4667.21

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
27.74	293.59	79.25

FRACTILE	POOL SIZE (100% OIL — MILLIONS OF BARRELS)
1.00	.039
.95	3.020
.75	18.228
.50	62.468
.25	218.754
.05	998.255
0.00	7105.729

AVERAGE POOL SIZE (MILLIONS)
233.70

Ivishak play and Echooka play (same area)



LISBURNE PLAY

The Lisburne play consists of structural or stratigraphic traps in dolomite reservoirs in the Lisburne Group of Pennsylvanian and Mississippian age. The Lisburne Group overlies the Kayak Shale and is overlain by the Echooka Formation. The group is present in outcrop south of the play area and in the subsurface to the west. It is absent from the postulated east-plunging nose of the Barrow arch (Tailleur and others, 1978). The southern boundary of the play generally follows the outcrop of these rocks and the northern boundary generally extends to the sea. The Lisburne Group thins northward and may reach a zero depositional edge somewhere south of the present coastline (K. Bird, personal communication). Occurrence of these rocks in the play area may also be significantly reduced by Cretaceous or Jurassic truncation.

Reservoir rocks consist of dolomite, most of which is concentrated in the upper half of the Mississippian section (Armstrong and Mamet, 1975). The dolomitic interval reaches a thickness of 550 feet in outcrop. Porosities of up to 13 percent have been measured in outcrop samples (Bird, unpublished data). Amount of dolomite and porosity may be expected to increase northward toward the basin margin.

Geochemical data from the Prudhoe area (Morgridge and Smith, 1972) suggests that the Lisburne is a poor source in the mature to overmature range. The underlying Kayak and Kekiktuk are slightly better source rocks but are expected to be gas prone. Oil and gas shows have been encountered in the Lisburne from nearby wells and dead asphaltic oil observed in outcrop (Bird, personal communication).

Postulated traps are small structures, possibly a large structure (Marsh anticline), numerous porosity pinchout stratigraphic traps and possible large stratigraphic traps if a truncation edge (Cretaceous or Jurassic) extends through the area.

8

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ____________ PLAY NAME: *Lisburne*

DATE EVALUATED: *5/19/80* REVISED: *6/2/80*

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)		.8	
	TIMING (T)		1	
	MIGRATION (M)		1	
	POTENTIAL RESERVOIR FACIES (R)		1	
	PLAY PROBABILITY (SxTxMxR=MP)		.8	
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)		.2	
	EFFECTIVE POROSITY (≥3%) (P)		.8	
	HYDROCARBON ACCUMULATION (C)		.5	good oil in outcrop
	PROSPECT PROBABILITY (TMxPxC=CP)		.08	
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	—	
		CARBONATE	1	
	HYDROCARBON MIX	GAS	.7	
		OIL	.3	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0	COMMENTS
AREA OF CLOSURE ($x10^3$ ACRES)	.6	2	10	20	40	50	100	
RESERVOIR THICKNESS (FT)	5	50	100	200	300	500	600	
EFFECTIVE POROSITY (%)	3	4	7	9	10	14	15	
TRAP FILL (%)	1	3	8	12	18	38	100	
RESERVOIR DEPTH ($x10^3$ FT)	.1	3	8	16	21	26	31	
NUMBER OF DRILLABLE PROSPECTS	2	3	5	7	12	20	25	
PROVED RESERVES ($x10^6$ BBLS; TCF)								

LISBURNE GAS FRACTION = .70

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

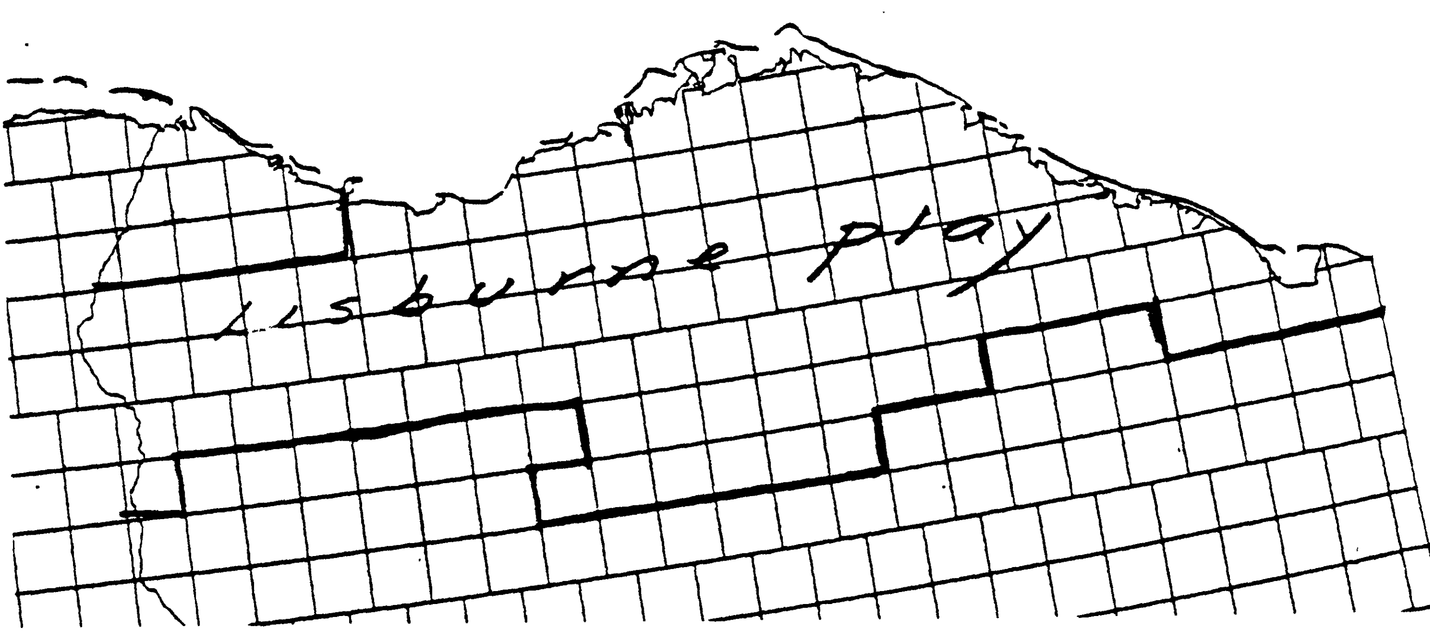
FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	294.52	77.96
.05	102.52	2018.39	499.37
0.00	3726.79	17138.69	4840.47

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
27.19	421.72	101.17

FRACTILE	POOL SIZE (100% OIL -- MILLIONS OF BARRELS)
1.00	.136
.95	4.434
.75	27.448
.50	89.869
.25	245.481
.05	963.924
0.00	10243.028

AVERAGE POOL SIZE (MILLIONS)
250.07

Lisburne play



KEKIKTUK PLAY

The Kekiktuk play consists of structurally or stratigraphically trapped sandstone reservoirs of the Kekiktuk Conglomerate of probable Mississippian age. The Kekiktuk overlies Franklinian sequence basement rocks and is overlain by the marine Kayak Shale. The formation is present in outcrop south of the play area and in the subsurface to the west. It is absent from the postulated east-plunging nose of the Barrow Arch near the Canning River (Tailleur and others, 1978). The southern boundary of the play generally follows the outcrop of these rocks and the northern boundary generally extends to the sea. The Kekiktuk consists of interbedded sandstone, shale, conglomerate, and coal generally deposited under nonmarine conditions (Brosge and others, 1962; Reed, 1968). Thickness and sandstone percentage change rapidly and generally decrease northward. Thus the northern depositional limit may occur somewhere south of the coastline. Jurassic or Cretaceous truncation may also reduce the areal extent of the play.

Reservoir rocks consist of sandstone as much as 100 to 200 feet thick in the Wildlife Range, but up to 1,200 feet of sandstone is present in the subsurface to the west in Mobil Mikkelsen Bay No. 1 (Bird, 1978). Reservoir properties are expected to be poor because outcrops are generally described as quartzite.

Geochemical data from the Prudhoe Bay area suggest that the Kekiktuk is a fair source rock and the overlying Kayak Shale is a poor source rock. Both are gas prone and mature to overmature. Oil shows are present in the Kekiktuk in Mobil Mikkelsen Bay No. 1.

Postulated traps are small structures, a possible large structure (Marsh anticline) and possibly large stratigraphic traps if a truncation edge (Cretaceous or Jurassic) extends through the sea.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ____________ PLAY NAME: *Kekiktuk*

DATE EVALUATED: *5/21/80* REVISED: *6/3/80*

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE	(S)	.7	
	TIMING	(T)	1	
	MIGRATION	(M)	1	
	POTENTIAL RESERVOIR FACIES	(R)	1	
	PLAY PROBABILITY (SxTxMxR=MP)		.7	
PROSPECT ATTRIBUTES	TRAP OCCURRENCE	(TM)	.2	
	EFFECTIVE POROSITY (≥3%)	(P)	.5	
	HYDROCARBON ACCUMULATION	(C)	.4	
	PROSPECT PROBABILITY (TMxPxC=CP)		.04	

	ATTRIBUTE									COMMENTS
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	1							
		CARBONATE	—							
	HYDROCARBON MIX	GAS	.7							
		OIL	.3							
	FRACTILES / ATTRIBUTE	PROB. OF EQUAL TO OR GREATER THAN: 100	95	75	50	25	5	0		
	AREA OF CLOSURE ($x10^3$ ACRES)	.6	5	10	20	40	50	200		
	RESERVOIR THICKNESS (FT)	5	20	50	75	150	300	500		
	EFFECTIVE POROSITY (%)	3	5	9	12	15	20	30		
	TRAP FILL (%)	1	3	9	15	22	40	75		
	RESERVOIR DEPTH ($x10^3$ FT)	2	5	9	17	22	27	32		
	NUMBER OF DRILLABLE PROSPECTS	2	3	5	7	12	20	25		
PROVED RESERVES ($x10^6$ BBLS; TCF)										

KEKIKTUK GAS FRACTION = .70

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

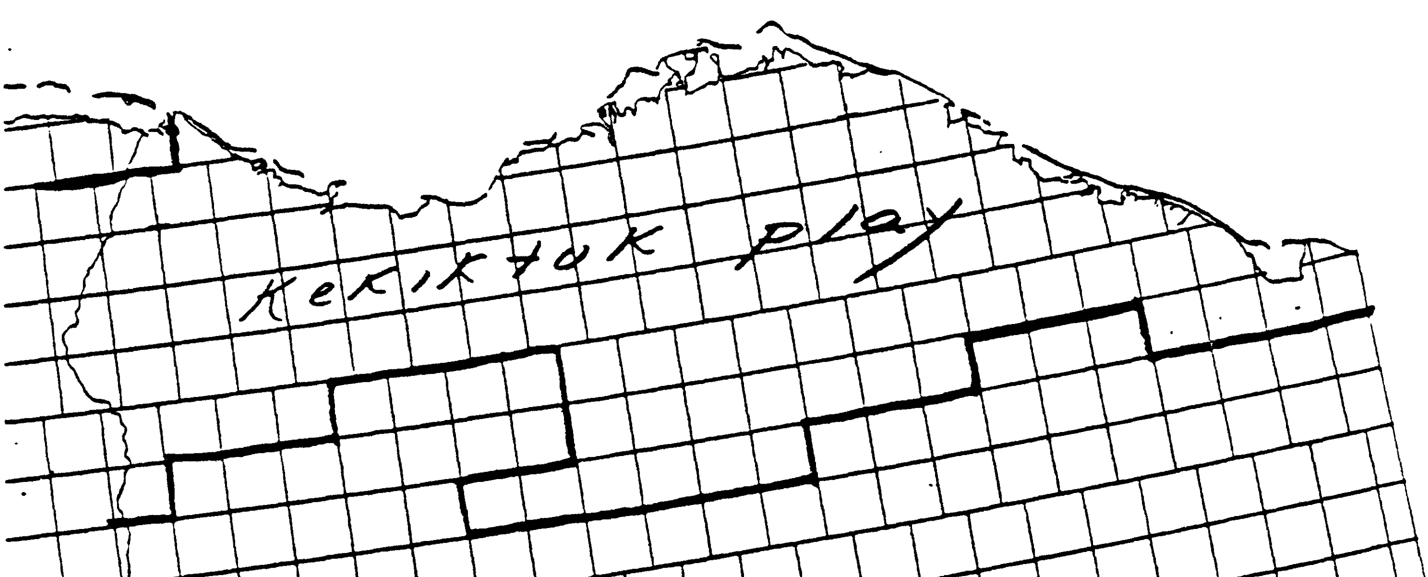
FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	20.32	3.96
.05	0.00	855.67	197.75
0.00	5090.76	96954.89	17009.63

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
13.50	246.93	56.82

FRACTILE	POOL SIZE (100% OIL — MILLIONS OF BARRELS)
1.00	.614
.95	2.998
.75	20.801
.50	62.133
.25	172.124
~~.05~~	915.934
0.00	18637.320

AVERAGE POOL SIZE (MILLIONS)
246.57

Kekiktuk play



KATAKTURUK PLAY

The Katakturuk play consists of structurally or stratigraphically trapped carbonate or sandstone reservoirs in the basement terrane. It is critical in this play that the reservoir rocks be charged and sealed by source rocks in the overlying Ellesmerian or Brookian sequence. Rocks in the basement terrane are folded and angularly overlain by younger sediments. The occurrence of reservoir rocks in the basement is therefore unpredictable.

The most promising reservoir unit is the Katakturuk Dolomite or Devonian-Silurian(?) age as much as 7,000 feet thick in outcrop (Dutro, 1970). In Exxon Canning River A-1 a test of 600 feet of Katakturuk flowed fresh water at a rate of 4,824 barrels per day. Other potential reservoir rocks include the Devonian Nanook Limestone and an unnamed quartzite.

Metamorphism of the basement rocks (Reed, 1968) precludes an indigenous source and makes the juxtaposition of younger source rocks (Jurassic, Cretaceous or Tertiary) critical for hydrocarbon accumulations in this play. Possible asphaltic hydrocarbons were described from the Katakturuk in Exxon Canning River A-1, while in Exxon Alaska State A-1 on Flaxman Island numerous oil shows were encountered in an unnamed dolomite.

Postulated traps are structural or stratigraphic traps in areas where truncation places Jurassic or younger rocks in contact with the basement.

10

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: ______________ PLAY NAME: *Katakturuk*

DATE EVALUATED: *5/21/80* REVISED: *6/2/80*

	ATTRIBUTE		PROB. OF FAVORABLE	COMMENTS
PLAY ATTRIBUTES	HYDROCARBON SOURCE (S)		.5	
	TIMING (T)		1	
	MIGRATION (M)		1	
	POTENTIAL RESERVOIR FACIES (R)		.6	
	PLAY PROBABILITY (SxTxMxR=PP)		.3	Oil Shows: Exxon Flaxman Id; Alaska State A-1
PROSPECT ATTRIBUTES	TRAP OCCURRENCE (TM)		.1	
	EFFECTIVE POROSITY (≥3%) (P)		.4	
	HYDROCARBON ACCUMULATION (C)		.3	
	PROSPECT PROBABILITY (TMxPxC=CP)		.012	
HYDROCARBON VOLUME PARAMETERS	RESERVOIR LITHOLOGY	SAND	→	sandstone may be present
		CARBONATE	1	
	HYDROCARBON MIX	GAS	.5	
		OIL	.5	

ATTRIBUTE \ FRACTILES (PROB. OF EQUAL TO OR GREATER THAN)	100	95	75	50	25	5	0	COMMENTS
AREA OF CLOSURE ($x10^3$ ACRES)	.6	2	10	20	40	50	100	
RESERVOIR THICKNESS (FT)	5	50	100	200	250	500	1000	
EFFECTIVE POROSITY (%)	3	3	4	5	6	8	15	
TRAP FILL (%)	1	3	8	12	18	25	50	
RESERVOIR DEPTH ($x10^3$ FT)	2	5	9	13	18	22	25	
NUMBER OF DRILLABLE PROSPECTS	→	1	1	2	3	4	6	
PROVED RESERVES ($x10^6$ BBLS; TCF)								

KATAKTURUK GAS FRACTION = .50

CONDITIONAL
<----------------RESOURCES IN PLACE---------------->

FRACTILE	OIL (MILLIONS)	GAS (BILLIONS)	BOE (MILLIONS)
1.00	0.00	0.00	0.00
.95	0.00	0.00	0.00
.75	0.00	0.00	0.00
.50	0.00	0.00	0.00
.25	0.00	0.00	0.00
.05	0.00	0.00	0.00
0.00	121.14	1765.31	309.70

AVERAGE OIL (MILLIONS)	AVERAGE GAS (BILLIONS)	AVERAGE BOE (MILLIONS)
.20	7.78	1.57

FRACTILE	POOL SIZE (100% OIL — MILLIONS OF BARRELS)
1.00	3.817
.95	6.410
.75	15.488
.50	42.031
.25	136.873
.05	320.007
0.00	359.354

AVERAGE POOL SIZE (MILLIONS)
101.37

Katakturuk play

APPENDIX II

Aggregated resource and pool size estimates for the William O. Douglas Arctic Wildlife Range as determined by the OMPRA Computer Model using 3000 Monte Carlo Passes

USGS WILLIAM O. DOUGLAS ANWR APPRAISAL 06/02/80

STATE OF NATURE INPUT DATA

KMAX	NPLAYS	N	M	NPLOTF	NDEBUG	NPFLAG	NPRINT	LES	IUSGS
6	10	7	3000	0	0	2	0	0	0

STARTING SEED = 654321

MARGINAL PLAY PROBABILITY	CONDITIONAL SUCCESS PROBABILITY	PLAY NAME
.100E+01	.800E-01	DEMARCATION
.100E+01	.450E+00	FLAXMAN
.100E+01	.160E+00	SABBATH
.100E+01	.900E-01	KEMIK
.100E+01	.500E-01	SAG/SHUBLIK
.100E+01	.700E-01	IVISHAK
.800E+00	.600E-01	ECHOOKA
.800E+00	.800E-01	LISBURNE
.700E+00	.400E-01	KEKIKTUK
.300E+00	.120E-01	KATAKTURUK

TOTAL ANWR OIL IN PLACE

PERCENTILE	(BILLIONS)
100	0.00
99	0.00
98	.03
97	.08
96	.12
95	.16
90	.38
75	1.12
50	2.71
25	5.87
10	11.29
5	17.03
4	18.67
3	20.44
2	24.86
1	31.99

AVERAGE OIL
4.850

TOTAL ANWR GAS IN PLACE

PERCENTILE	(TRILLIONS)
100	0.00
99	.51
98	.87
97	1.09
96	1.28
95	1.44
90	2.16
75	4.33
50	8.41
25	15.14
10	25.19
5	33.93
4	37.14
3	40.51
2	46.75
1	61.74

AVERAGE GAS
11.903

TOTAL RESOURCES IN PLACE

(EQUIVALENT BARRELS OF OIL)

PERCENTILE	(BILLIONS)
100	0.00
99	.33
98	.49
97	.61
96	.75
95	.86
90	1.31
75	2.48
50	4.74
25	8.52
10	14.71
5	20.53
4	22.17
3	24.79
2	28.85
1	36.64

AVERAGE RESOURCES
6.938

PERCENTILE	TOTAL ANWR POOL SIZE (100% OIL - MILLIONS OF BBL)
100	.04
99	1.38
98	2.50
97	3.61
96	4.85
95	6.18
90	14.02
75	54.09
50	216.43
25	720.71
10	2101.78
5	3810.57
4	4506.89
3	5557.92
2	7325.41
1	10803.95

AVERAGE POOL SIZE
891.78

MEAN	STD	LOGMEAN	LOGSTD
891.777	2403.522	19.054	1.942

29346

APPENDIX III

Definitions of terms for the oil and gas appraisal data form as used in the William O. Douglas Arctic Wildlife Range

DEFINITIONS OF TERMS FOR THE OIL AND GAS

APPRAISAL DATA FORM AS USED IN THE WILDLIFE RANGE ASSESSMENT

AREA OF CLOSURE (10^3) ACRES: The area of closure is the number of acres above the spill point. Fractiles indicate the relative confidence that the area of closure is at least that large. A minimum threshold value of 600 acres is used at the 100th fractile. The probability that this minimum value is achieved is incorporated in the trap occurrence (TM) judgment under prospect attributes.

EFFECTIVE POROSITY (%): The effective porosity value for the reservoir expressed as a percent. Porosity values in the fractiles indicate the relative confidence that the porosity is at least that good. A value of 3% is used as the minimum cut off. The probability that the minimum cut off value is achieved is incorporated in the effective porosity (P) judgment under prospect attributues.

EFFECTIVE POROSITY (P): Porosity of a potential reservoir facies (R) is the interconnected void space which may hold hydrocarbons. The probability for effective porosity describes the probability that porosity equal to or greater than 3% will be found in a randomly selected prospect within the play area. The effective porosity is based on subsurface porosity maps that use measured porosities where available.

HYDROCARBON ACCUMULATION (C): Hydrocarbon accumulation (C) is the existence of oil and gas in at least one percent of a trap. The probability for hydrocarbon accumulation describes the probability that there was a locally favorable combination of source (S), timing (T), and migration (M) so that hydrocarbons will be found in a randomly selected trap within the play area.

HYDROCARBON MIX: The hydrocarbon mix is an indication of the tendency of accumulations in the play to be either oil or gas. The term is expressed as a ratio which sums to one (A + B = 1.0). A mix of .8 gas and .2 oil would indicate an 80% chance that an accumulation in the play would be gas, or that 8 of 10 accumulations in the play on the average would be gas. This parameter is based on concepts of thermal maturity and type of organic material of the source, and on the type of hydrocarbon observed in wells and seeps.

HYDROCARBON SOURCE (S): A unit or rock that has generated and expelled oil or gas in sufficient quantity to form accumulations in the play area and meeting the minimum criteria for organic richness, kerogen type, and thermal maturity. Minimum richness values for clastic source beds are 0.5 wt % organic carbon, and for carbonate source beds 0.35 wt % organic carbon. The kerogen type for oil is amorphous and herbaceous and for gas is herbaceous and coaly. Minimum requirements for thermal maturity for oil are vitrinite reflectance values of 0.65%, and for condensate and gas vitrinite reflectance values of 1.2%.

HYDROCARBON VOLUME PARAMETERS: Hydrocarbon volume parameters refer to generic reservoir characteristics within the play and include assumed lithology of reservoir (sand or carbonate) and hydrocarbon mix (oil or gas). Other hydrocarbon volume parameters are (1) area of closure, (2) potential reservoir thickness, (3) effective porosity, (4) trap fill, (5) prospect depth, and (6) number of drillable prospects. The distribution of these last six parameters is expressed in fractiles from 100 to 0.

MIGRATION (M): Migration (M) is the movement of hydrocarbons through a conduit; a conduit can be a porous and permeable clastic or carbonate rock, fracture, joint, or fault.

MINIMUM THRESHOLD VALUES: The following minimum threshold values were selected for the hydrocarbon volume parameters: area of closure (600 acres), reservoir thickness (5 ft), effective porosity (3%), trap fill (1%), and reservoir depth (100 ft). The probabilities that these threshold values are achieved are incorporated in the prospect attribute judgments, except in the case of minimum reservoir depth which is incorporated in the number of drillable prospects. The minimum threshold values were selected to lie below any reasonable economic limit for the area under consideration so that economics would not enter into the evaluation procedure.

NUMBER OF DRILLABLE PROSPECTS: The number of drillable prospects is an estimate of the potential number of valid targets that would be considered for drilling if the play were fully explored. Fractiles indicate the relative confidence that the number of drillable prospects is at least that large. Closure is estimated using seismic data, subsurface geologic mapping or inference from nearby areas. Only prospects of 600-acre size or greater and at depths of 100 ft or greater are considered. The number of drillable prospects also includes the probability that the reservoir formation may be absent in parts of the area.

OIL AND GAS APPRAISAL DATA FORM: The data on the oil and gas appraisal form are to be used in a computer simulation of the geology as related to the hydrocarbon distribution in the area under consideration and to develop a probablistic resource appraisal for this area.

PLAY: The play consists of one or more prospects in a common or relatively homogeneous geologic setting which can be explored for by using geological, geochemical, and geophysical techniques.

PLAY ATTRIBUTES: The common elements or play attributes are hydrocarbon source (S), timing (T), migration (M), and potential reservoir facies (R). The probability that a play attribute is generally favorable in the play area is expressed as a decimal number from 0 to 1.0, where 1.0 is absolute certainity that the attribute exists. Proved reserves in the play area cause all play attributes to be set to 1.0.

PLAY PROBABILITY (MP): The play probability (MP) is the product of the probability of hydrocarbon source (S), timing (T), migration (M), and potential reservoir facies (R), or S x T x M x R = MP. Play probability may also be thought of as the joint probability that all the common play attributes are concurrently favorable somewhere in the play area. Proved reserves in the play area are an indication that all play attributes are favorable and therefore the play probability is 1.0.

POTENTIAL RESERVOIR FACIES (R): Potential reservoir facies are porous and permeable sandstone or carbonate rocks capable of containing and producing hydrocarbons.

PROSPECT: The prospect is a potential hydrocarbon accumulation of at least 600 acres in size.

PROSPECT ATTRIBUTES: The prospect attributes are trap occurrence (TM), effective porosity (P), and hydrocarbon accumulation (C). The probability that the prospect attributes will exist in a randomly selected prospect, conditional upon all the play attributes being favorable, is expressed as a decimal number from 0 to 1.0, where 1.0 is absolute certainty that the attribute exits. In a play for which the regional characteristics are all favorable, the existence of a hydrocarbon accumulation at any particular prospect location is conditioned upon the simulataneous occurrence of an effective trap occurrence (TM), adequate porosity (P), and the locally favorable combination of source, timing, and migration expressed by the term hydrocarbon accumulation (C).

PROSPECT PROBABILITY (CP): The joint prospect probability (CP) is the product of the individual probabilities of trap occurence (TM), effective porosity (P), and hydrocarbon accumulation (C), or TM x P x C = CP. The prospect probability may also be thought of as the probability that any randomly selected prospect would be accumulation given that all the play attributes are favorable. The product of prospect probability and play probability (CP x MP) is the exploratory success ratio. The dry-hole risk factor is one minus this product.

TIMING (T): Timing expresses the relationship between the time of trap formation and the time hydrocarbons moved into or through the area. The trap must form before or during, not after, hydrocarbon migration in order to form an accumulation.

TRAP OCCURRENCE (TM): The trap restricts hydrocarbon migration and can be related to structure, stratigraphy, or a combination of both. The probability for trap occurrence describes the probability that a trap of at least 600 acres areal extent with a reservoir or vertical closure of at least 5 ft will be found to exist in a randomly selected prospect within the play area.

TRAP FILL (%): Trap fill is the hydrocarbon volume in a trap expressed as a percent of the total porous volume under closure. A minimum threshold value of 1% is used at the 100th fractile. The probability that this minimum value is achieved is incorporated in the hydrocarbon accumulation (C) term in the prospect attributes section. Elements that affect trap fill include: (1) source rock richness and thermal maturation, (2) hydrocarbon drainage area, (3) size of structure, and (4) porosity (permeability) of reservoir rock. Fractile values indicate the relative confidence that the trap is at least that full.