UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A Comparison of the Play-analysis Technique as Applied in Hydrocarbon Resource Assessments of the National Petroleum Reserve in Alaska and of the Arctic National Wildlife Refuge

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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ABSTRACT

A play-analysis method of petroleum resource assessment was recently developed by the U.S. Department of the Interior and was used successfully in the evaluation of two northern Alaska frontier areas: the National Petroleum Reserve in Alaska (NPRA) and the coastal plain of the Arctic National Wildlife Refuge (ANWR). The assessment procedure entails the input of subjective probabilistic geologic judgments into a computer which, in turn and within minutes, generates a set of probabilistic resource estimates. The two assessment areas are part of the same North Slope petroleum province, and are generally similar except for their size and for the absence of seismic and well data for the ANWR. The 17 plays in the NPRA and the 10 in the ANWR were defined stratigraphically, with the exception of one tectonically defined play in the NPRA.

Our results show that although the assessment area of the NPRA is approximately ten times larger than that of the ANWR coastal plain, the undiscovered in-place oil and gas resources are estimated to be nearly the same in both areas, although pool sizes are estimated to be larger in the ANWR.

These two assessments were the first ever undertaken by the U.S. Geological Survey using the play-assessment technique, and our experience suggests that several small modifications in the method would improve its efficiency and enhance its reliability. The advantages of this method over conventional procedures include its capability to furnish a record of probalistic geologic judgments on large amounts of data, with the provision for easy revision and updating as new information becomes available.

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INTRODUCTION

The U.S. Geological Survey and the Office of Minerals Policy and Research Analysis, U.S. Department of the Interior have developed a play-analysis method for petroleum resource assessment. The U.S. Geological Survey utilized this method for assessing the undiscovered hydrocarbon resources of two frontier areas of Alaska: the National Petroleum Reserve in Alaska (NPRA) and the coastal plain of the Arctic National Wildlife Refuge (ANWR).

In this play-analysis method, geologists provide (1) their professional judgments on the relative favorability of various geologic conditions necessary for petroleum accumulation within a given play area and (2) quantification of a set of geologic variables. An automated Monte Carlo technique generates a set of probabilistic resource estimates including a pool-size distribution.

The play, which is the basic unit of assessment in this method, is defined as an area consisting of one or more prospects in a common or relatively homogenous setting, the prospects of which can be explored by conventional methods. Use of the play method yields probability distributions of undiscovered in-place hydrocarbon resources and pool sizes for each play, as well as a prospect list for each play which may be combined with other data to generate an economic analysis.

Our play-analysis method is an adaptation of the method used by the Geological Survey of Canada to assess Canada's petroleum resources (Canada Department of Energy, Mines, and Resources, 1977). It was developed with a twofold purpose in mind: (1) To provide an assessment of the undiscovered hydrocarbon resources of frontier petroleum basins; and (2) To formulate the assessment results in the manner most compatible with a procedure for economic analysis.

This paper discusses two play-analysis assessments which were conducted at the request of the U.S. Congress. The initial study, that of the Petroleum Reserve (U.S Department of the Interior, 1979), consisted of a resource estimate as well as an economic analysis. The second project, an assessment of the hydrocarbon resources of the Arctic National Wildlife Refuge (Mast and others, 1980 and in press), did not include an economic analysis.

The purpose of this report is to compare these two frontier area assessments in terms of their geology, available data, assessment procedures, and assessment results. The paper includes recommendations for procedural improvements, as well as suggestions for selected areas of research that might facilitate the desired refinements in procedure. Finally, validation of this method is presented in the form of a comparison of post-assessement exploration results with those values predicted by the play method.

Other publications describing this play-analysis method include Bird (1981), Mast and others (1980 and in press), Miller (1981, 1982, and in press), and White (1979 and 1981). Detailed information on the assessment of the coastal plain of the Wildlife Refuge is presented by Mast and others (1980 and in press), and on the assessment of the Petroleum Reserve by Bird (in press). The economic and policy analysis of the Petroleum Reserve is described by Bugg and others (in press) and the U.S. Department of the Interior (1979). A comparison of the several hydrocarbon resource estimates of the Petroleum Reserve by means of various methods (including the play-analysis method) is presented by Bird and Powers (in press). A concise review of hydrocarbon assessment methods is given by White and Gehman (1979).

GEOLOGIC COMPARISON

The Petroleum Reserve and the petroleum-prospective area of the Wildlife Refuge (Fig. 1) are each a part of the Alaskan North Slope petroleum province. They have grossly similar sedimentary rock sequences and a shared tectonic history. The petroleum geology of the Petroleum Reserve is summarized in Bird (1981), Carter and others (1977), and Gryc (in press); that of the Wildlife Refuge is summarized in Mast and others (1980 and in press).

In both areas the petroleum-prospective rocks consist of two distinct sedimentary assemblages: (1) The older, relatively thin, continental margin assemblage of northern derivation known as the Ellesmerian sequence; and (2) the younger, thick orogenic assemblage of southern derivation known as the Brookian sequence (Lerand, 1973). Economic basement in both areas consists of pre-Mississippian metamorphosed sedimentary rock with minor amounts of igneous rock.

The Ellesmerian sequence, Mississippian to Early Cretaceous in age, is generally less than 6,000 ft (1.5 km) thick and consists of fluvial clastic or shallow-marine clastic and carbonate deposits in the northern third of the province, grading southward to relatively deep marine chert and shale. Limited mostly to the northern third of the province, reservoir rocks in this assemblage are compositionally mature, exhibit fair-to-excellent porosity and permeability, and include the productive Prudhoe Bay reservoirs.

The areal distribution of Ellesmerian rocks in the northern part of the province is irregular. In the Petroleum Reserve the distribution is controlled by onlap of the source terrain and erosion prior to rifting; whereas, in the Wildlife Refuge the distribution is controlled by erosion prior to rifting and possibly by the rifting itself.

In the north, a regional tectonic event in Late Jurassic and Early Cretaceous time produced uplift, rifting, and subsidence thus eliminating the northern sediment sourceland and terminating Ellesmerian deposition. In the south, by comparison, subsidence, continental subduction, and a rising orogenic landmass (the ancestral Brooks Range) initiated Brookian deposition.

The edge of the Barrow platform is interpreted as the rift margin, and the Barrow arch is interpreted as a hingeline along which rocks sagged or were faulted down to the north. The Colville trough, the thrust belt, and the adjacent fold belt are all products of the Brooks Range orogeny. These tectonic features are shown in Figure 2.

The Brookian sequence, latest Jurassic or earliest Cretaceous to Tertiary in age, consists of 20,000 ft (6 km) or more of fluvial to deep-marine clastic sediments shed from the ancestral Brooks Range and deposited in the adjacent Colville trough (Fig. 2). Filling of the trough was by progradation, which

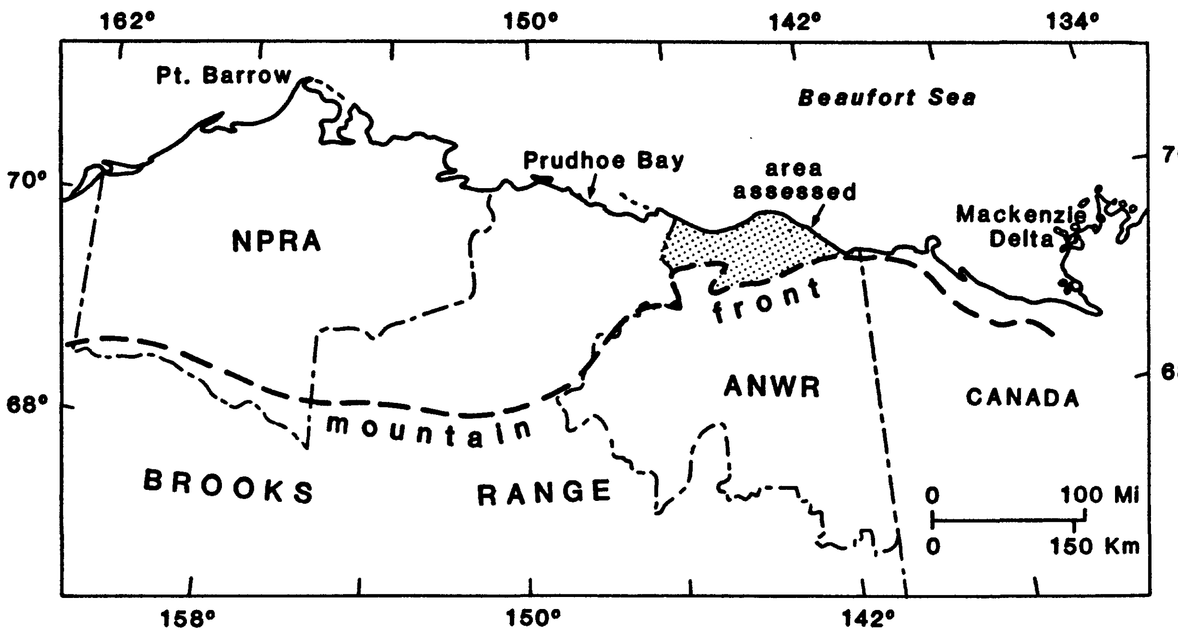

Figure 1. Regional index map showing location of the National Petroleum Reserve in Alaska (NPRA), the Arctic National Wildlife Refuge (ANWR), and the area of resource assessments.

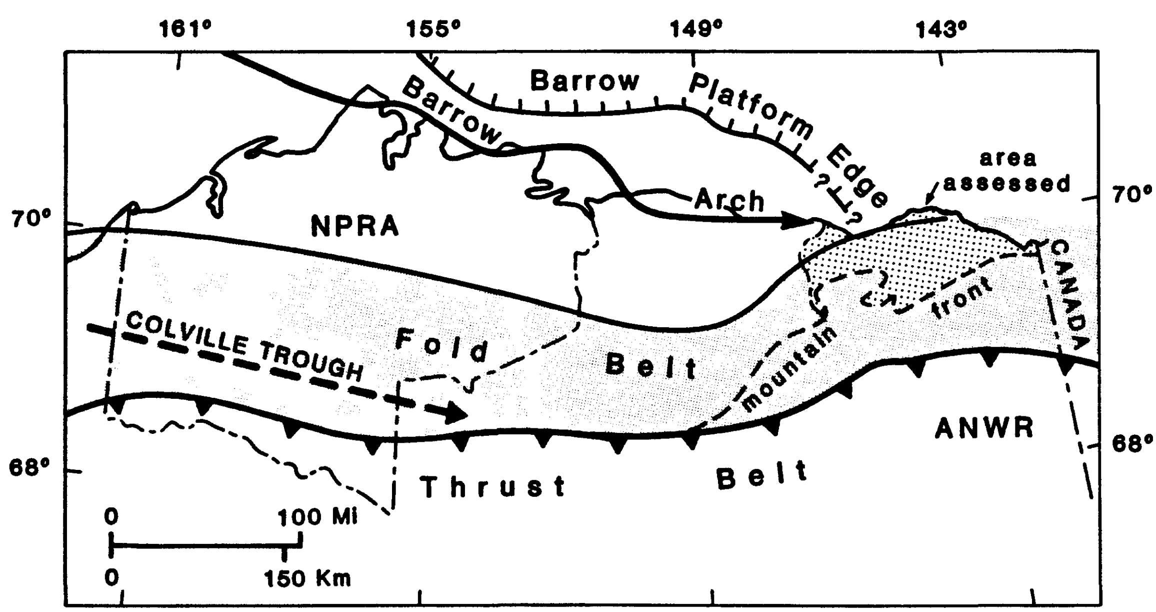

Figure 2. Map of northern Alaska showing the Mesozoic-Cenozoic structural features referred to in this report.

proceeded with a pronounced northeasterly trend. A relatively thin distal marine shale with a relatively high percentage of organic material was deposited over a wide area at the base of the Brookian sequence and ahead of the prograding trough fill. These relationships are illustrated in Figure 3.

From the foregoing discussion, in conjunction with Figures 2 and 3, we may draw the following comparative conclusions. The Petroleum Reserve consists of three east-trending subparallel tectonic elements: The gentle south flank of the Barrow arch, the fold belt, and the thrust belt. In contrast, the Wildlife Refuge assessment area lies at the intersection of the Barrow platform margin, the Barrow arch, and the fold belt. Ellesmerian reservoir rocks in the Petroleum Reserve onlap the Barrow arch and display deteriorating reservoir quality southward, at increasingly greater depths. Although the Ellesmerian reservoir rocks in the Wildlife Refuge assessment area may be mostly missing by erosion or faulting, where present they exhibit facies ideal for good reservoir development. Brookian rocks in the Petroleum Reserve are older and display generally poorer reservoir characteristics than those in the Wildlife Refuge.

DATA COMPARISON

When comparing the data from these two Alaskan frontier areas, one major difference is readily seen to be the existence of subsurface information (wells and reflection seismic) for the Reserve, and the lack of such data for the Refuge. Data from surface geologic mapping, source-rock geochemistry, porosity and permeability measurements, and aeromagnetic and gravity surveys are otherwise similar for both areas. These data types are summarized for each area in Table 1. The assessment of the Wildlife Refuge was aided immeasurably by several wells along the western border of the Refuge and by reconnaissance seismic data offshore.

TABLE 1. COMPARISON OF DATA AVAILABLE FOR PETROLEUM RESOURCE ASSESSMENTS IN THE NPRA AND THE ANWR

	NPRA	ANWR
REFLECTION SEISMIC	6 x 12-MILE GRID	NONE
WELLS	78	NONE
SURFACE GEOLOGY	YES	YES
GRAVITY	YES	YES
AEROMAGNETICS	YES	YES
SOURCE-ROCK GEOCHEMISTRY	YES	YES
POROSITY AND PERMEABILITY MEASUREMENTS	YES	YES

COMPARISON OF PLAYS

Plays in both the Petroleum Reserve and the Wildlife Refuge were defined stratigraphically by individual potential reservoir rock unit, except in the disturbed belt of the Brooks Range and adjacent foothills in the Reserve where one play was defined as a tectonic assemblage. Where structural relations or source-rock to reservoir-rock relations were considered to be significantly different, more than one play was established within a single stratigraphic interval.

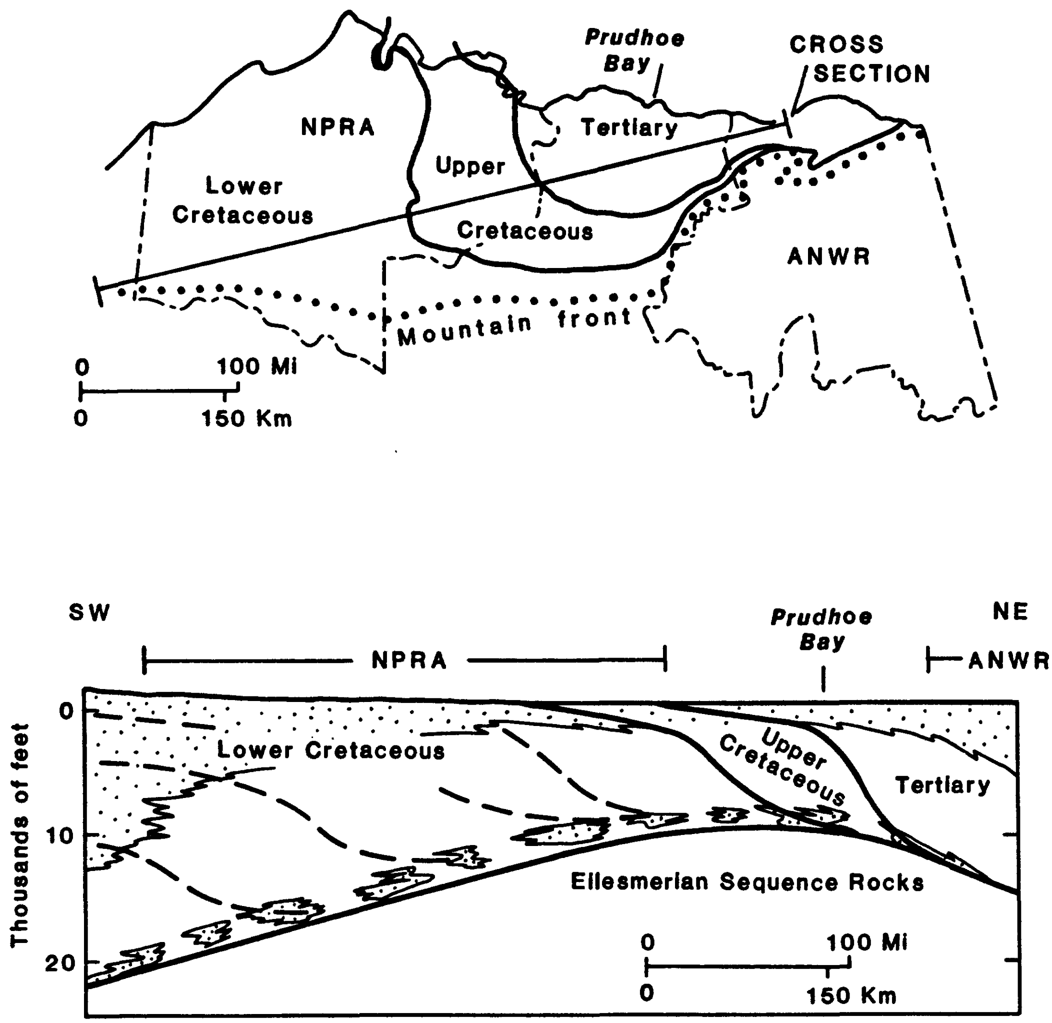

Figure 3. Map and cross section of northern Alaska showing the areal distribution and style of deposition of Brookian (southern source) rocks which fill the Colville trough (Fig. 2).

In the Petroleum Reserve, 17 plays were established and assessed; this compares with 10 plays in the Wildlife Refuge. The relationship of plays to stratigraphy for each area is summarized by the time-stratigraphic diagrams in Figure 4. Because of geologic similarities many of the plays in both areas are in the same stratigraphic intervals. However, in the Refuge, one play was established for pre-Mississippian intra-basement carbonate rocks (play number 10, Fig. 4). No comparable plays are known to exist in the Petroleum Reserve. Play descriptions and maps are presented in Mast and others (1980 and in press) for the Refuge and in Bird (in press) for the Reserve.

ASSESSMENT PROCEDURES

The U.S. Department of the Interior play-analysis method of resource appraisal divides the geologic characteristics of potential hydrocarbon accumulations into three categories: (1) play-specific, (2) prospect-specific, and (3) reservoir-specific (see data form, Figure 5). When combined, categories 1 and 2 provide the risk factor. Category 3 (plus the number of drillable prospects attribute of category 1) provides the data necessary for volumetric calculations of resource and pool size. Subjective probability judgments are made for each of these three categories by geologists familiar with the local geology, and these probabilities are then combined by a Monte Carlo method to yield probability distributions of pool size and in-place hydrocarbon volumes for each play. Further use of the Monte Carlo method provides an aggregation of hydrocarbon volumes for all plays, yielding a total resource estimate for the area. Descriptions of the assessment method are presented in Bird (1981 and in press), Mast and others (1980 and in press), Miller (1981 and 1982), and White (1979 and 1981). Definitions of assessment terms on the data form (Fig. 5) are presented by Bird (in press) and Mast and others (1980 and in press). A flow chart showing the steps involved in a single Monte Carlo pass is presented in Miller (1981 and in press).

In the assessment procedure, two committees were organized to provide the input. Committee members included (in nearly equal numbers) experts on the petroleum geology of the area in question and experts in petroleum geology and resource appraisal. The first committee, after a thorough review of the geology and establishment of the plays, reviewed the definitions of assessment terms and probability concepts and then gave subjective probability judgments on each category for each play. The second committee reviewed the work of the first in order to ensure adherence to established procedures and definitions of terms. This procedure was employed in the separate assessments of the Petroleum Reserve and Wildlife Refuge, utilizing many of the same experts for both areas.

The assessments of both areas were supported by the expertise in statistics, probability theory, and computer science of the personnel from the Office of Minerals Policy and Research Analysis, Department of the Interior. These experts had previously developed the formal computer model for the method, and they were present to provide the on-site computer capability which made it possible for the resource estimates to be generated within minutes of completion of a play assessment data form.

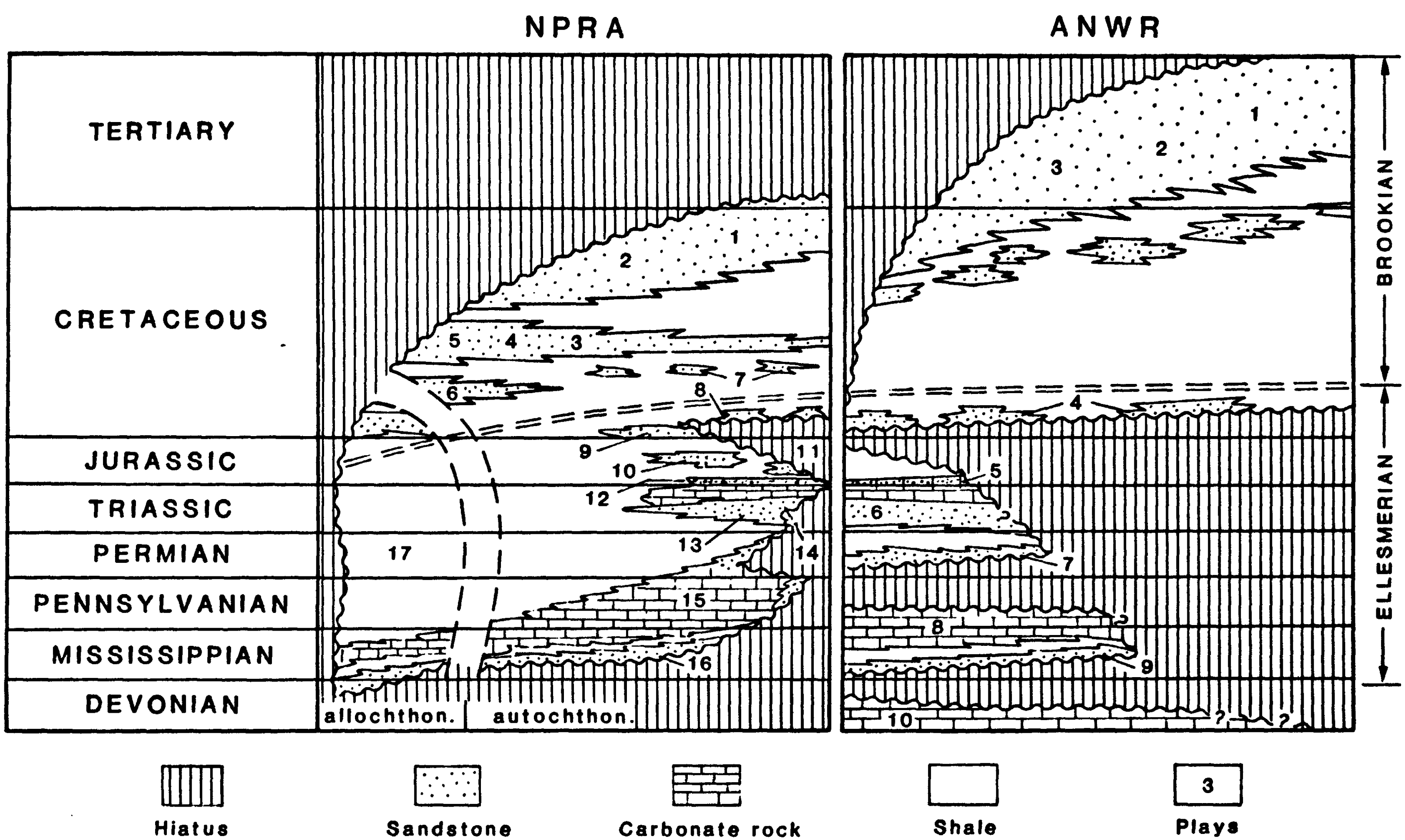

Figure 4. Time-stratigraphic diagrams of the NPRA and the ANWR comparing stratigraphy and plays. The stratigraphic relations in the ANWR diagram are representative of the westernmost part of the Refuge. Numbers assigned to plays in each area are mutually exclusive.

OIL AND GAS APPRAISAL DATA FORM

EVALUATOR: U.S. Geological Survey PLAY NAME: ____________

DATE EVALUATED: ____________ REVISED: ____________

<table>
<tr><th colspan="6">ATTRIBUTE</th><th colspan="3">PROB. OF FAVORABLE</th><th>COMMENTS</th></tr>
<tr><td rowspan="5">PLAY ATTRIBUTES</td><td colspan="5">HYDROCARBON SOURCE (S)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">TIMING (T)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">MIGRATION (M)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">POTENTIAL RESERVOIR FACIES (R)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">PLAY PROBABILITY (SxTxMxR=MP)</td><td colspan="3"></td><td></td></tr>
<tr><td rowspan="4">PROSPECT ATTRIBUTES</td><td colspan="5">TRAP OCCURRENCE (TM)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">EFFECTIVE POROSITY (≥3%) (P)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">HYDROCARBON ACCUMULATION (C)</td><td colspan="3"></td><td></td></tr>
<tr><td colspan="5">PROSPECT PROBABILITY (TMxPxC=CP)</td><td colspan="3"></td><td></td></tr>
<tr><td rowspan="11">HYDROCARBON VOLUME PARAMETERS</td><td rowspan="2">RESERVOIR LITHOLOGY</td><td colspan="4">SAND</td><td colspan="3"></td><td rowspan="2"></td></tr>
<tr><td colspan="4">CARBONATE</td><td colspan="3"></td></tr>
<tr><td rowspan="2">HYDROCARBON MIX</td><td colspan="4">GAS</td><td colspan="3"></td><td rowspan="2"></td></tr>
<tr><td colspan="4">OIL</td><td colspan="3"></td></tr>
<tr><td rowspan="2">FRACTILES / ATTRIBUTES</td><td colspan="7">PROB. OF EQUAL TO OR GREATER THAN</td><td rowspan="2"></td></tr>
<tr><td>100</td><td>95</td><td>75</td><td>50</td><td>25</td><td>5</td><td>0</td></tr>
<tr><td>AREA OF CLOSURE ($\times 10^3$ ACRES)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>RESERVOIR THICKNESS (FT)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>EFFECTIVE POROSITY (%)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TRAP FILL (%)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>RESERVOIR DEPTH ($\times 10^3$ FT)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">NUMBER OF DRILLABLE PROSPECTS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="9">PROVED RESERVES ($\times 10^6$ BBLS; TCF)</td><td></td></tr>
</table>

Figure 5. Example of data form employed in recording judgments in the U.S. Department of the Interior play-analysis method.

The data forms were completed according to committee consensus after group discussion of each item; individual analysts' judgments were not recorded per se. Judgments were made by referring to appropriate maps, cross sections, well logs, or other data displays. Where data were sparse or non-existent (such as trap fill), analog comparisons were made with other North Slope fields, or Canadian data, or the experience of the committee members.

Because the play-method assessments were in many respects "learning experiences" for the scientists involved, the computer-generated resource distributions were accepted with a proper skepticism. However, because of the short time lapse from scientific judgment to computer output, the scrutiny of the computer-generated results was conducted with the details of the geologic discussions within easy recall. An unacceptable computer result was one which was at odds with subjective professional judgments. Such a situation provoked intense discussion and review of the input judgments, and occasionally resulted in a revision of these judgments. This facet of the procedure improved both the final resource estimates as well as the geologists' understanding of the method.

COMPARISON OF ASSESSMENT RESULTS

Assessment results for the Petroleum Reserve and the Wildlife Refuge are compared in Figure 6 which shows estimated volumes of in-place undiscovered oil and gas and estimated pool sizes. The similarity in the estimated volumes of oil and gas is remarkable in view of the tenfold difference in size of the two assessment areas: NPRA = 23.6 million acres; coastal plain of the ANWR = 2.2 million acres. Pool-size estimates show significantly larger values in the Wildlife Refuge compared to the Petroleum Reserve.

The similar hydrocarbon volume estimates can be supported by a consideration of regional geologic characteristics. The assessed portion of the Wildlife Refuge is located mostly within a fold-belt structural province which affects young (Tertiary) basin-filling deposits with fair-to-excellent reservoir characteristics overlying rich Cretaceous source rocks. However, Ellesmerian rocks, productive at Prudhoe Bay, may be absent from part or nearly all of the area. In contrast, the much larger assessment area of the Petroleum Reserve shows widespread occurrences of both the Ellesmerian and Brookian rocks. The Ellesmerian rocks in the Petroleum Reserve are generally more deeply buried than at Prudhoe Bay, they thin to the north, and they occur in the generally structureless coastal plain province. Brookian rocks in the Reserve are older than Brookian rocks in the Refuge; they display poor-to-fair reservoir quality, fair source-rock quality, and the structural traps which are present are often highly faulted.

Based on the estimates, the preponderance of hydrocarbon resources occurs in Brookian rocks both in the Petroleum Reserve (Bird, in press) and in the Wildlife Refuge (Mast and others, 1980 and in press). The Prudhoe Bay area, in apparent contrast, has proven commercial reserves only in Ellesmerian reservoirs. However, the recent discoveries in the Point Thomson area, 80 km east of Prudhoe Bay (van Dyke, 1980) and the announcement of 18-40 billion barrels in-place of low-gravity oil in Brookian reservoirs just west of Prudhoe Bay (Oil and Gas Journal, 1982) suggest that even in the Prudhoe Bay area the proportion of in-place hydrocarbon volumes in Brookian and

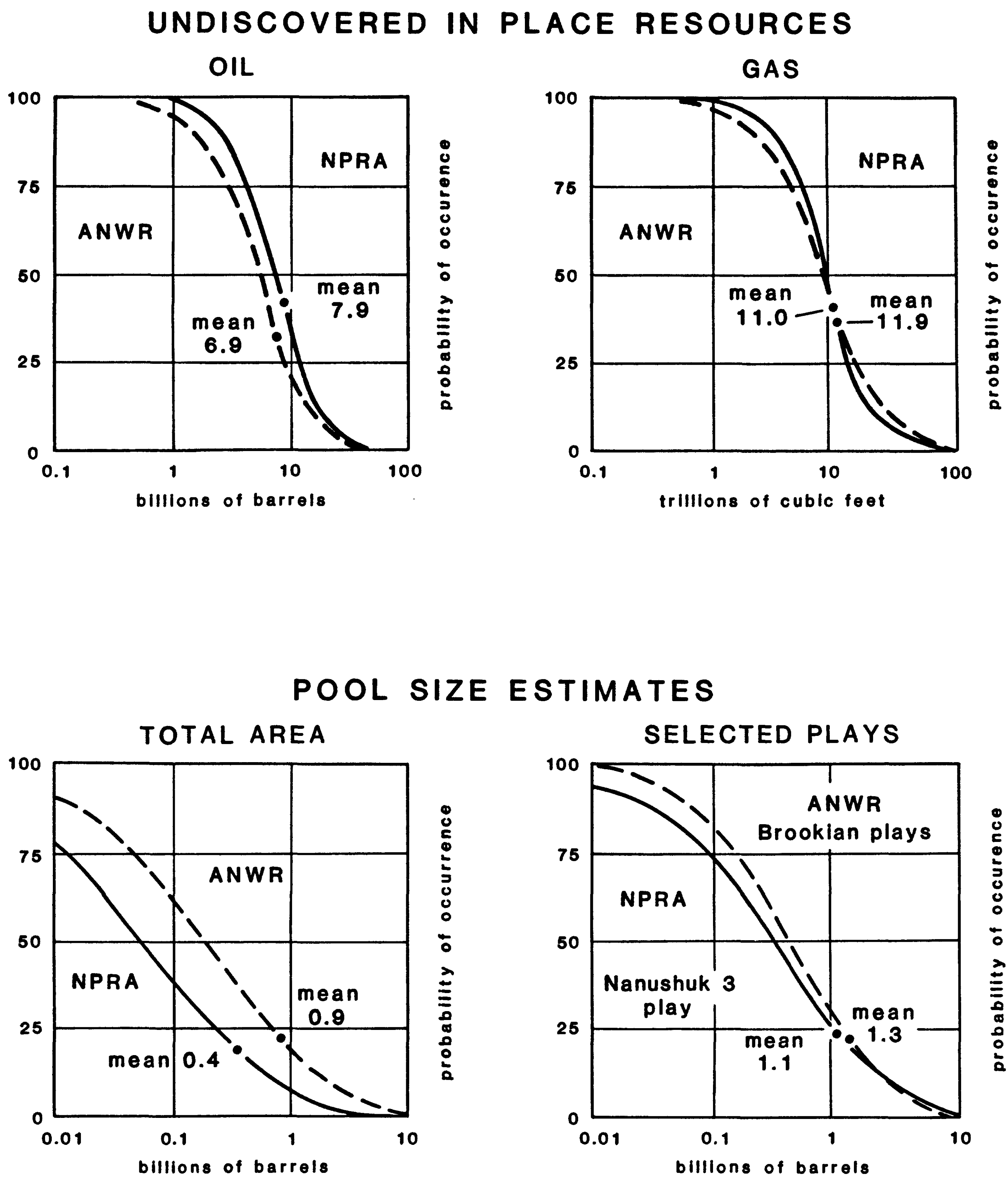

Figure 6. A comparison of probability distributions of undiscovered oil and gas resources and pool sizes for the NPRA (solid curve) and the ANWR (dashed curve). The larger ANWR pool sizes compared to the NPRA pool sizes (lower left diagram) are the result of very large pool sizes in ANWR Brookian plays. These plays are geologically most similar to the NPRA Brookian Nanushuk 3 play (number 5 on Fig. 4) and comparison shows they have similar pool sizes (lower right diagram).

Ellesmerian reservoirs may be similar to the proportions for our two assessment areas.

Pool-size estimates in this play-analysis method are dependent upon: (1) Number of drillable prospects, (2) area of closure, (3) reservoir thickness, (4) reservoir depth, (5) effective porosity, (6) trap fill and (7) connate water saturation. The larger estimated pool sizes for the Wildlife Refuge as compared to the Petroleum Reserve may be supported by consideration of the same regional geologic characteristics as discussed above. For the Wildlife Refuge, the number of drillable prospects and area of closure parameters were most difficult to estimate because of a sparsity of this type of information. Estimates for these two parameters were accomplished by counting and measuring the few surface-mapped structures within the Refuge, and counting and measuring any offshore seismically-controlled structures that appeared to project onshore. On the basis of detailed examinations of offshore seismic records, the committee increased this relatively small number of onshore prospects by an order of magnitude, reasoning that when fully explored with a close-spaced seismic grid, what were perceived to be a few large structures would be found to actually consist of numerous smaller structures.

SUGGESTIONS FOR PLAY METHOD IMPLEMENTATION

Suggested modifications to the play method are directed toward improving the understandability of the method, facilitating the required geologic judgments, and refining the reliability of the estimates:

1. A clearly written set of definitions of play-method terms, including example probability judgments, is critical to the proper employment of the method by any geologist/assessor.
2. Along with a clear understanding of what is required in forming a judgment, the geologist/assessor needs a complete, well-illustrated summary of the essential petroleum geology data. Such a comprehensive data summary is time-consuming to assemble, but experience suggests that its availability improves the accuracy of the estimates and lessens the time required for the actual assessment process. An individual, or even a committee, can recall only a limited number of data items at any one time. Therefore, data summaries are mandatory.
3. One facet of the data summary and data review process should be a standardized, objective system for the evaluation of dry holes (failed prospects). Although such an evaluation was not part of our methodology, this evaluation could be accomplished by utilizing the prospect attribute part of the data form (Fig. 5). For the target interval(s) in each dry hole, judgments could be made on the favorability of these attributes (trap occurrence, effective porosity, and hydrocarbon accumulation). This procedure would insure that each dry hole is critically examined and a judgment rendered on why it is dry. A collection of such judgments for a play would also be helpful in making the difficult play and prospect attribute judgments required on the data form.
4. An assemblage of analogs would be most helpful for assessments of frontier areas where data are often incomplete or nonexistent. At present, the lack of such data as required for estimating number of drillable prospects and area of closure makes the task more difficult than if these data were available.

5. The possibility that resource estimates by the play-analysis method are statistically biased is a concern of several committee members. Their concern is with the effect of dependent relationships among geologic input parameters which in this method are assumed to be independent. Dependent relations are those in which a change in one parameter implies a value (or limited range of values) in another parameter. The Monte Carlo simulation technique employed in this play-analysis method assumes most parameters to be independent and that any combination of values is equally likely. For example, effective porosity generally decreases as reservoir depth increases. The Monte Carlo technique, in selecting any combination of values, may combine maximum reservoir depth with maximum porosity or minimum reservoir depth with minimum porosity. Both combinations may be geologically unrealistic for a given play. The committee's concern is that these two unlikely combinations, once selected, may not cancel each other and may therefore introduce bias into the assessment results. The effect of dependent parameters could be investigated by changing one dependent parameter while holding all others constant through multiple computer runs and observing the changes in resource estimates. Dependance of varing degrees exists among the following assessment parameters: (1) effective porosity and reservoir depth, (2) area of closure and trap fill, (3) area of closure and reservoir thickness, (4) trap fill and reservoir thickness, (5) effective porosity and trap fill, (6) number of drillable prospects and area of closure. Documentation of dependent relations could simplify the data form by the elimination of some (dependent) parameters.

POST-ASSESSMENT EXPLORATION RESULTS

How accurate are the resource estimates? Of course, only time and continued exploration can provide the ultimate determination. For one year after the final resource estimate, the exploration drilling program continued in the NPRA. The results of this exploration, combined with North Slope analog data, offer encouraging validation of our method.

Prior to the last assessment (May 1980), gas was discovered in Walakpa-1 in a sandstone reservoir in the Pebble Shale play (Fig. 7). Data indicated that this is a stratigraphically trapped accumulation of unknown size. In the drilling season following that last assessment, a successful follow-up well (Walakpa-2) was drilled, and this encountered gas in the same reservoir, three miles to the south and 600 ft (180 m) deeper. To date the areal extent of the reservoir and its average thickness (and thus, the size of the accumulation) remain unknown.

Although present information is insufficient to calculate the total volume of the Walakpa gas field, useful estimates of this volume can be obtained through the use of an analog and a set of aeromagnetic anomalies. The analog is a similar sandstone in the Prudhoe area. The geologic details of the Walakpa gas-bearing reservoir compare favorably to the lower Cretaceous Put River Sandstone (Ellesmerian) in the Prudhoe Bay field (Jamison and others, 1980). The areal distribution and thickness of the Put River

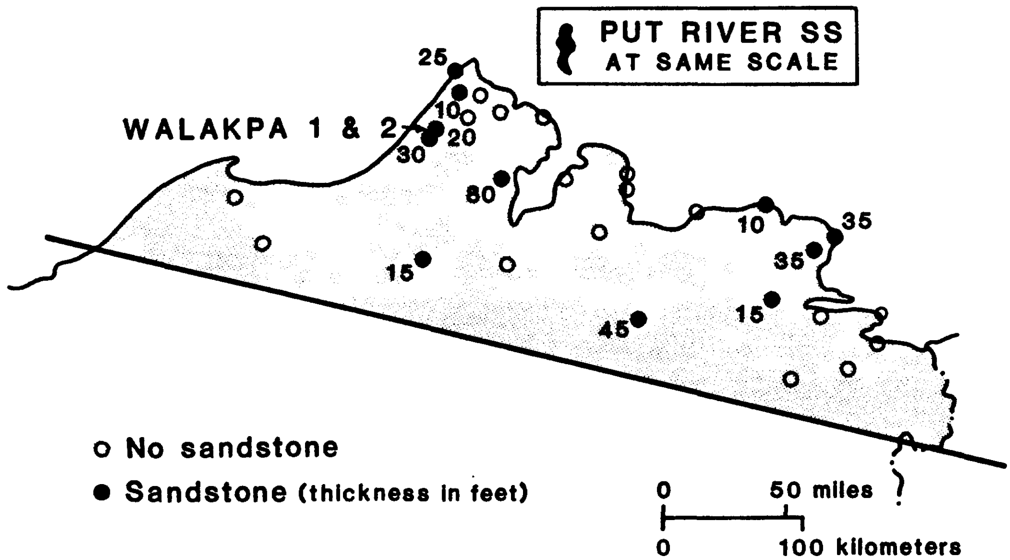

Figure 7. Map of the Pebble Shale play area (shaded) in northern NPRA showing the location of wells which penetrate this play interval and the thickness of sandstone encountered in this play interval. This play is number eight in Figure 4.

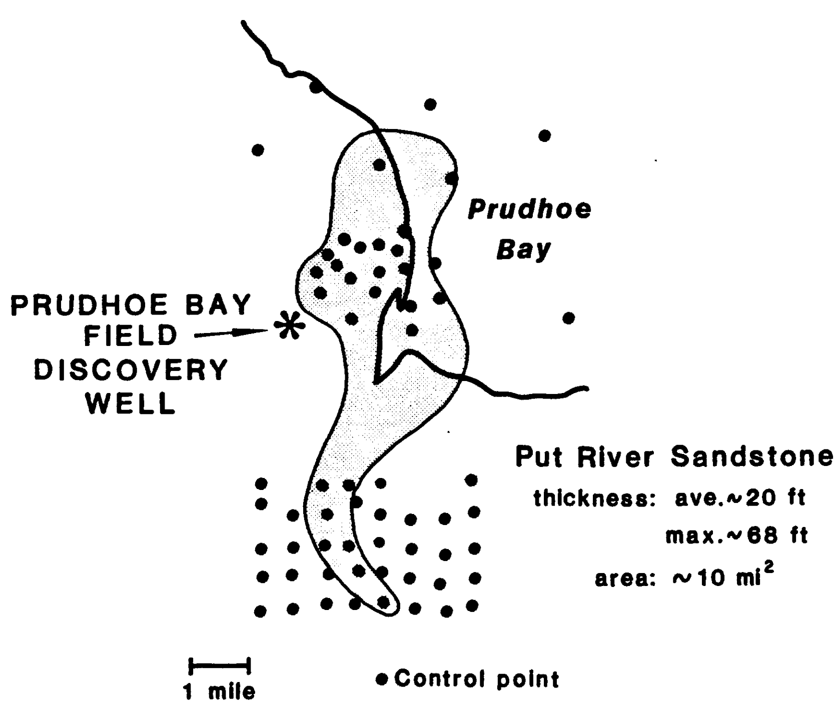

Figure 8. Map of an area adjacent to Prudhoe Bay showing the areal distribution of the Lower Cretaceous Put River Sandstone (modified after McIntosh, 1977).

Sandstone, summarized in Figure 8, are adapted from McIntosh (1977). These data, when combined with data from the Walakpa wells, result in a calculated in-place gas volume of 63 BCF (billion cubic feet; Table 2). The gas accumulation may be even larger if the high wave-number magnetic anomalies reported by Donovan and others (in press) result from microseepages outlining the accumulation. The Walakpa wells lie near the center of a roughly circular area bordered by a discontinuous ring of magnetic anomalies. Assuming that these anomalies mark the areal limits of the field and combining this amount of area with data from the Walakpa wells results in a calcualted in-place gas volume of 412 BCF (Table 2). In terms of probability, the smaller volume (Put River Sandstone analogy) would have a greater chance of occurrence than the larger volume (aeromagnetic anomalies). In Figure 9 these two calculated volumes are compared to the estimated volumes for the entire Pebble Shale play by the play-analysis method. A re-assessment of the Pebble Shale play at this time would probably result in increased hydrocarbon resource estimates.

TABLE 2 CALCULATIONS OF IN-PLACE GAS VOLUME
FOR THE WALAKPA GAS FIELD

Volume Equation	Put River Ss Analog	Aeromagnetic anomalies
AREA	6400 acres	42,000 acres
x x	x	
RESERVOIR THICKNESS*	20 feet	20 feet
x x	x	
GAS VOLUME PER ACRE-FOOT OF RESERVOIR**	0.49 MMCF/AC-FT	0.49 MMCF/AC-FT
= =	=	
IN-PLACE VOLUME (in billions of cubic feet - BCF)	63 BCF	412 BCF

* Estimated average thickness from Walakpa No. 1 and No. 2.
**Value calculated from porosity and pressure measurements from Walakpa No. 2 (Gruy and Associates, 1981).

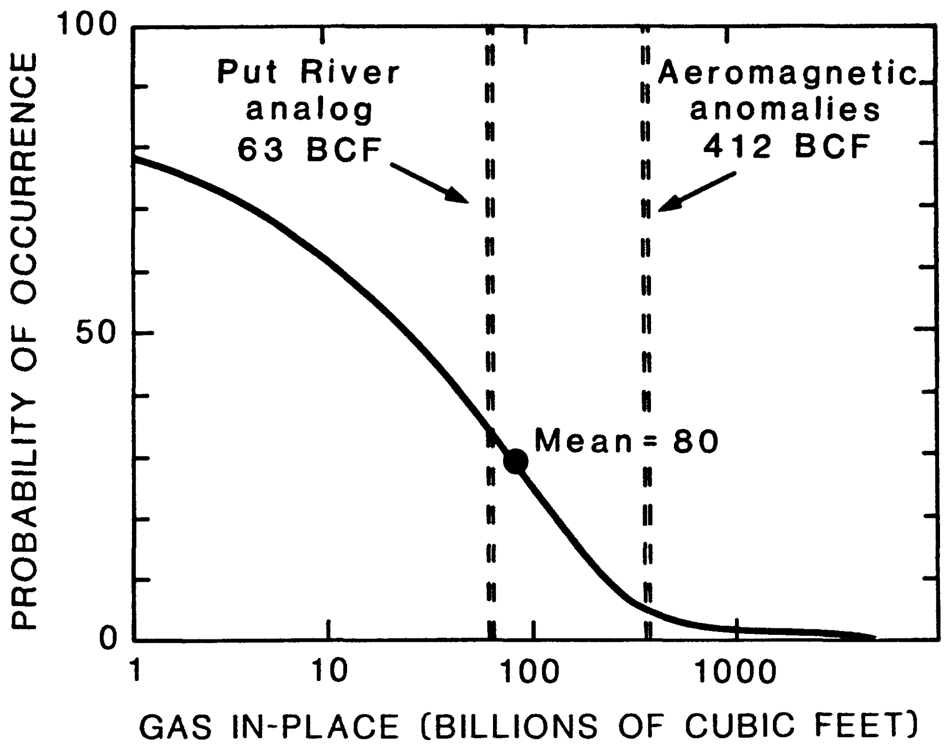

Figure 9. A comparison of two calculated in-place gas volumes for the Walakpa gas field (dashed vertical lines) to the May, 1980 play-analysis estimates of in-place gas for the entire Pebble Shale play (solid curve and mean value).

SUMMARY AND CONCLUSIONS

The play-analysis method of resource assessment, as utilized by the U.S. Geological Survey, has been successfully applied to two frontier areas in northern Alaska. This method requires that the geologist/assessor formulate input judgments on pertinent geologic characteristics of a given play area, and the resource estimates are then generated by the computer. This procedure acknowledges the geologist's expertise in purely scientific speculation as well as the computer's recognized capability for sophisticated manipulation of data. Another advantage to this method is that it provides a record of geologic judgments on large amounts of data and includes provision for easy revision as new information becomes available.

In this method an absence of data results in greater uncertainty in resource estimates. Substantial increases in uncertainty in the results occur when seismic data are not available for determination of prospect number and size. Likewise, a lack of subsurface control for determination of reservoir characteristics also increases the uncertainty of the resource estimates. These limitations influenced the Wildlife Refuge assessment, but, in this instance of a relatively small assessment area, were believed to have been compensated for by projection of data from nearby areas and by use of analog comparisons.

Most of the hydrocarbon resources for both assessment areas are estimated to occur in southern-source (Brookian) reservoirs. Recent oil discoveries in Brookian reservoirs in the Prudhoe Bay sector of the North Slope suggest that a similar relationship may even exist in this area where all commercial oil presently comes from Ellesmerian reservoirs.

Post-assessment exploration of the NPRA Pebble Shale play supplied new information which, when combined with North Slope analog data, demonstrated a hydrocarbon volume calculation in remarkably good agreement with the computer-generated resource estimates.

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