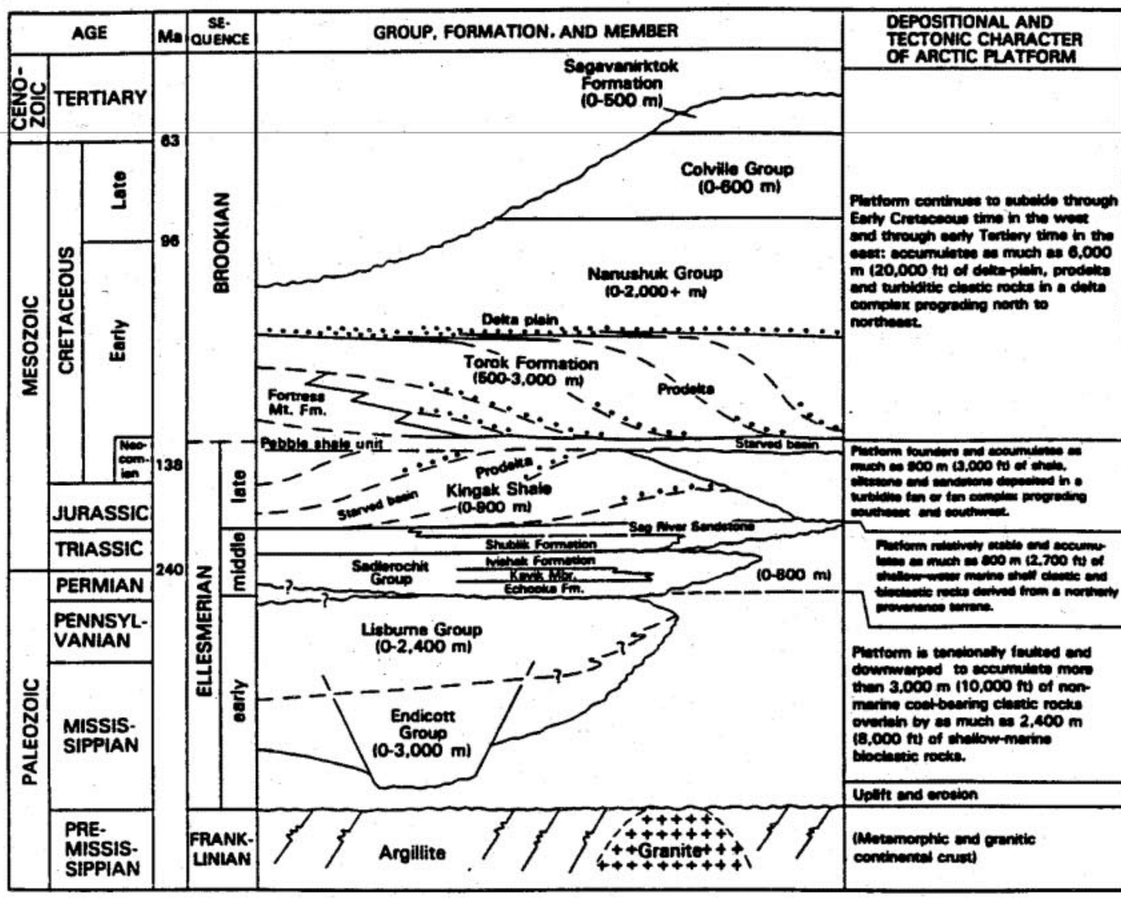
U. S. Department of the Interior
Bureau of Land Management

Alaska State Office
222 West 7th, #13
Anchorage, Alaska 99513

Oil and Gas Assessment of the Utukok Special Management Area, National Petroleum Reserve in Alaska

Robert J. Bascle and
Richard L. Foland



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Summary

The Utukok Caribou/Grizzly Special Management Area (USMA) and the Utukok Caribou Deleted Area (UCDA) in the western part of the National Petroleum Reserve in Alaska have a low probability of having economically recoverable oil and gas resources based on BLM classification standards in Handbook H-1624-1.

The shallow potential reservoir rocks in the area are thin and have low porosity and permeability values, at least as exposed at the surface and in the nearest wells. The deeply buried potential reservoir rocks appear to be below the oil preservation window, and any hydrocarbons that they may contain would probably be natural gas. The source rocks in the area tend to have low organic carbon content of a gas-prone nature. No subsurface geological data exists for the area, but extrapolations from the surface geology, from the subsurface geology of the nearby test wells, and from reflection seismic data hold little promise for the oil and gas potential of the USMA and UCDA areas.

While the available data shows little promise for the area, subsurface data from within the area and new exploration concepts could change the assessment presented here. In this regard, it should be emphasized that no wells have been drilled within the confines of the USMA or the UCDA, that is, this area has not been evenly lightly explored for oil or gas.

Remote even by north slope standards, nothing of the known fold and thrust belt structural style characterizing southwestern NPRA's geology distinguishes its petroleum potential from less environmentally sensitive NPRA areas to the north and east. In fact, interpretation of the United States Geological Survey 1988 Alaskan north slope hydrocarbon assessment suggests southwestern NPRA is the least hydrocarbon rich part of the Reserve.

Oil and Gas Assessment for the Utukok Special Management Area, National Petroleum Reserve in Alaska

1. Introduction

The Record of Decision on Oil and Gas Leasing and Development in the National Petroleum Reserve (NPRA) in Alaska, dated May 1983, created areas within the NPRA which are either: (a) deleted from oil and gas leasing, (b) deferred from oil and gas leasing pending further study, or (c) exposed to oil and gas leasing though subject to special management. The Utukok Caribou Deleted Area (UCDA) and the Utukok Caribou/Grizzly Special Management Area (USMA)[1], situated in the southwestern NPRA (*Figures 1 and 2*), are such regions. To date no oil and gas leases have been granted and no hydrocarbon exploration wells have been drilled in either area.

BLM Handbook H-1624-1 requires that an area containing a U.S. Geological Survey (USGS) "play" receives a "high" classification for oil and gas potential (See Appendix A). Under this scheme, all 23 million acres of NPRA would have a "high" classification and would be managed accordingly. This classification scheme is too broad for land management purposes in NPRA. The authors of the BLM Handbook recognize "the nearly ubiquitous presence of hydrocarbons in sedimentary rock" and allow for departure from the strict guideline cited above. A critical examination of available geological and geophysical data and of the USGS's resource estimates for the plays beneath the USMA and UCDA warrants a lower classification of the hydrocarbon potential for the USMA and UCDA.

1 Defined in the NPRA Environmental Impact Statement, plate 1, 2/83.

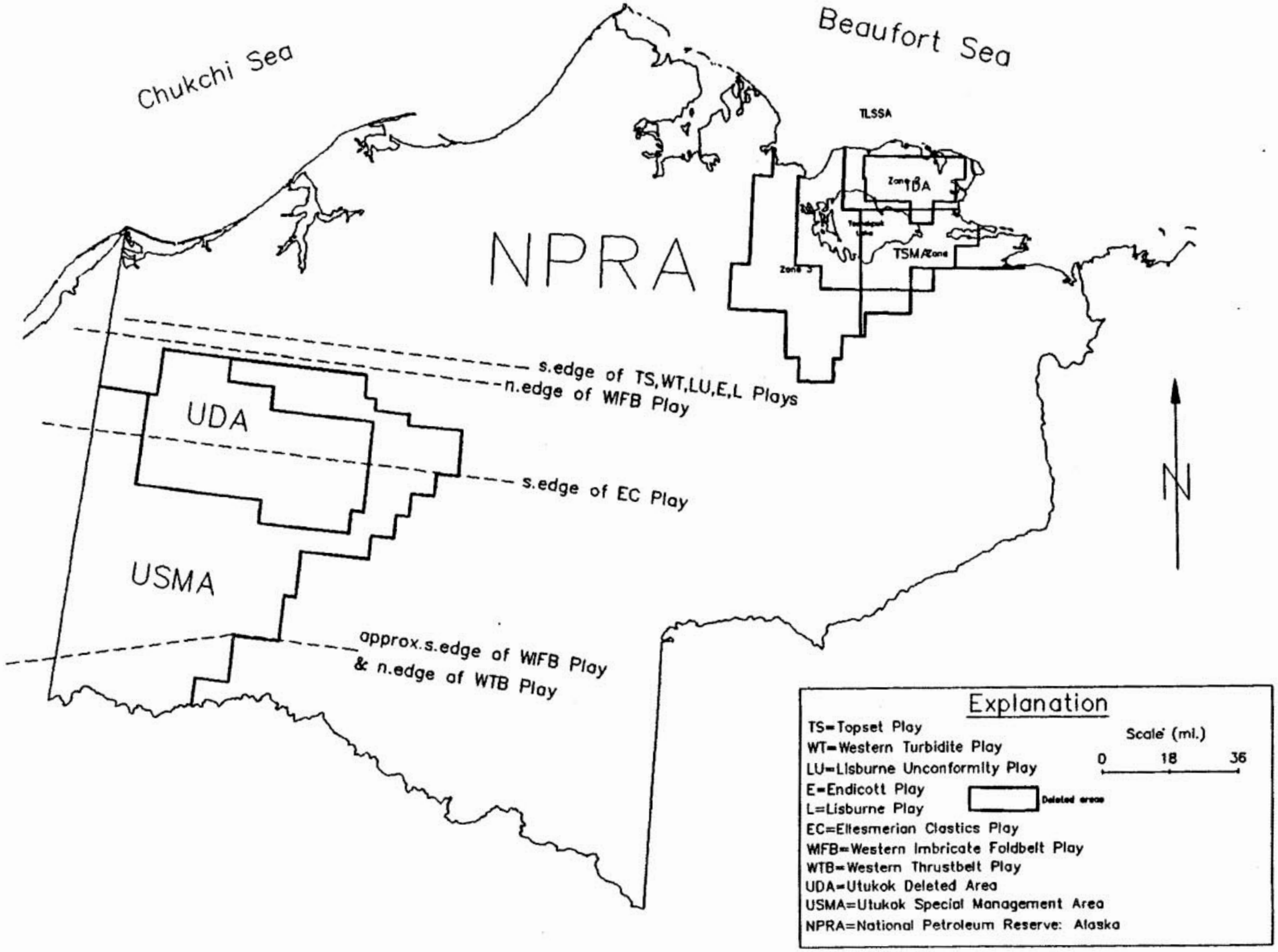


Figure 1.
Location of the UCDA and USMA and the edges of the USGS 1988 NSHA plays.

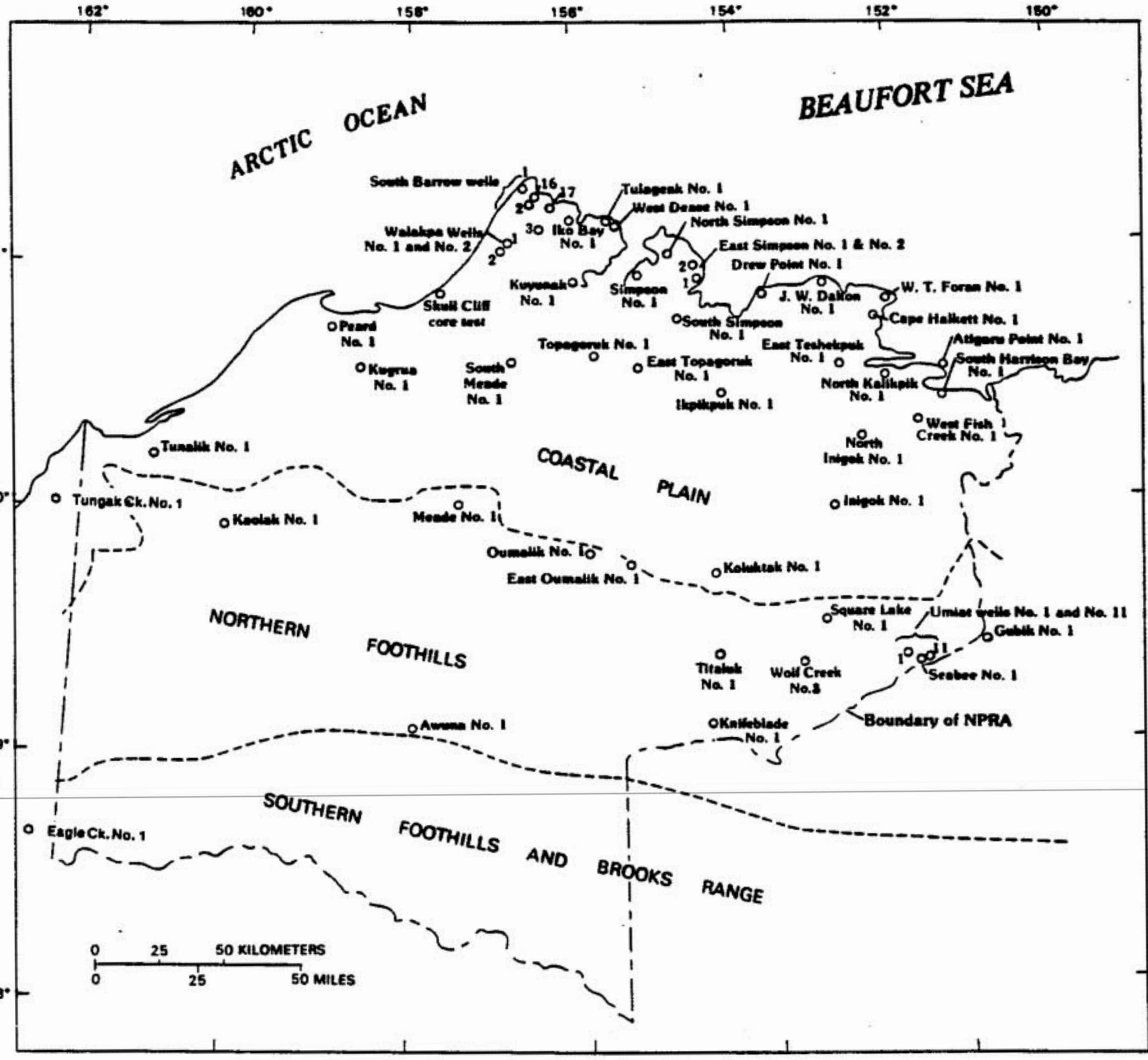


Figure 2.
Well locations. (modified from Bird, 1988c)

2. Surface and Subsurface Data Availability

The USGS has investigated the geology of Alaska's North Slope geologic province since the early 1900s. Investigations began in earnest with the USGS participation in the U.S. Navy's (USN) Naval Petroleum Reserve No. 4 (now National Petroleum Reserve in Alaska, or NPRA) exploration program of 1944-1953.

Chapman and Sable (1960), building on previous work, defined the geologic framework of most of the Utukok-Corwin Region of the North Slope, the area which contains the USMA and the UCDA. Six wells have been drilled in the general vicinity (*Figures 1 and 2*). Oil and gas shows were recorded (Bird, 1988a). The USN drilled the Kaolak Test Well No. 1, which is several miles north of the USMA, in 1951, and the Meade Test Well No. 1, which is about 22 miles northeast of the USMA, in 1950 (Collins, 1958). The USGS supervised the drilling of the Awuna Test Well No. 1, which is about 20 miles east of the USMA, in 1980 and 1981, and the Tunalik Test Well No. 1, which is about 21 miles north of the USMA and UCDA, in 1978-1980. Unocal drilled the Tungak Creek No. 1 well about 15 miles west of the northern UCDA and USMA, and Chevron drilled the Eagle Creek No. 1 well about 17 miles west of the southern USMA.

Collins (1958) reports on the results of the drilling of the Meade and Kaolak Test Wells. Chapman and Sable (1960), working from previously collected surface data, from surface outcrops, and from aerial photographs produced the first geologic map of the southwestern portion of the NPRA and the area west of the NPRA to the coast. Subsequent investigations provide additional data on the geology exposed at the surface. Husky Oil NPR Operations, Inc. (1983) and the USGS report on the wells that Husky drilled for the government's exploration program, including the Awuna Test Well No. 1 and the Tunalik Test Well No. 1. These wells provide the nearest available subsurface data. USGS Professional Paper 1399 (Gryc, 1988) contains a compilation of reports on the USGS's NPRA investigations. This professional paper supersedes numerous other reports by the USGS on the NPRA and should be consulted for more details.

Seismic surveys run for the Navy's exploration programs of 1944 through 1953 and 1974 through May 1977 and the USGS's exploration program of June 1977 through May 1982 provide a window to the subsurface geology. While the seismic surveys are of crucial importance to the assessment of the area and the selection of drillable targets, they do not provide the critical subsurface geological data needed for reservoir-rock and hydrocarbon-source-rock characterizations.

3. Structural Geology

The potential for structural hydrocarbon traps beneath the UCDA and USMA ranges from low to moderate. Generally, the potential varies with geographic position; it improves from south to north (*Figure* 3). The southern part of the area has low potential because of intense faulting and folding. The central part of the area has less intense faulting and folding, but shale-rich sedimentary rocks breach through the overlying, relatively sandstone-rich sedimentary rocks. The northern part of the area has still less intense folding, and the shale-rich sedimentary rocks have not breached through the sandstone-rich section.

The USMA and UCDA overlie sections of all physiographic provinces of Alaska's North Slope: the Brooks Range province, the southern foothills province, the northern foothills province, and the coastal plain province. Intensity of deformation decreases from south to north through these provinces.

Mayfield, Tailleur, and Ellersieck (1988) report that the Brooks Range physiographic province consists of hundreds of thrust sheets that "contain parts of structurally overlapping sequences that are composed of sedimentary, metasedimentary, and (or) igneous rocks." For the DeLong Mountains part of the province, which extends into the USMA, they group the thrust sheets into seven allochthons. Five of these allochthons consist mostly of sedimentary rocks that range in age from Ordovician, Devonian or Mississippian at their bases to Early Cretaceous at their tops. Two allochthons consist of distinctive igneous sequences of Triassic or Jurassic age. Incompetent rocks, such as shales and chert, have suffered intense deformation "and in some places there are numerous complex disharmonic folds." The allochthons are thrust over the rocks of the Fortress Mountain Formation and may be interthrust with the Fortress Mountain in the subsurface, but a dearth of subsurface data does not allow the characterization of the subsurface structure and the relationships of the allochthons to the Fortress Mountain Formation.

The intensity of deformation decreases to the north. The southern foothills province occupies the outcrop belt of the Fortress Mountain Formation, and maybe a few miles north of the outcrop belt,

Figure 3. Structural map of western NPRA. (after Kirschner and Rycerski, 1988)

and extends from the northern edge of the DeLong Mountains allochthons to about the Driftwood anticline (*Figure 3*). The geologic and structural maps of NPRA (Mayfield, Tailleur, and Kirschner, 1988; Kirschner and Rycerski, 1988) show numerous anticlines, synclines and overturned beds in the southern foothills province. This style and intensity of deformation undoubtedly extends some depth into the subsurface, but the available seismic data does not adequately resolve the subsurface structure.

The northern foothills physiographic province, in the USMA and UCDA, corresponds to the area approximately from the Driftwood anticline to about ten miles north of the Norseman anticline. The Carbon Creek Fault Zone (CCFZ) cuts through the area on a northwest-southeast trend. Long, linear, north-verging, thrust-fault-cored, detached anticlines characterize the structures to the southwest of the CCFZ and the CCFZ itself. In most of these anticlines, the shales of the Torok Formation breach through the sandstone-siltstone-shale sequence of the overlying Nanushuk Group. These anticlines have more steeply dipping northern limbs than southern limbs. The Torok shales in the cores of the anticlines are more complexly folded and faulted than the overlying Nanushuk Group sediments on the limbs of the anticlines. To the northeast of the CCFZ in the UCDA and USMA, the Torok Shales do not breach through the Nanushuk Group sediments.

The coastal plain province lies to the north of the northern foothills and corresponds to the area overlain by unconsolidated Quaternary sediments. In the USMA and UCDA, the southern limit of the coastal plain province corresponds to a meandering line which trends east-west at about the latitude of the Norseman anticline. Buried, plunging anticlines and synclines trend approximately east-west through the area. These compressional structures cease just to the north of the UCDA and USMA (Chapman and Sable, 1960; Mayfield et al., 1988; Kirschner and Rycerski, 1988).

4. Reservoir Potential

The USMA and UCDA area have mainly structural-trap exploration targets; the relative paucity of data makes it difficult, at best, to identify stratigraphic traps. The potential reservoir characteristics in the area look poor from both the surface data and the subsurface data from the nearest test wells. The area has few potential reservoir formations, and these usually have poorly sorted, fine-grained, low-porosity sandstones. Low porosity in a non-hydrocarbon-bearing zone is not, in itself, unequivocally detrimental to porosity existing at some other location within the potential reservoir rock. A formation that has physically or chemically unstable components could, nonetheless, maintain a high primary porosity, through the early migration of hydrocarbons into a reservoir rock. Alternatively, high secondary porosity could develop through chemical leaching of unstable mineral components.

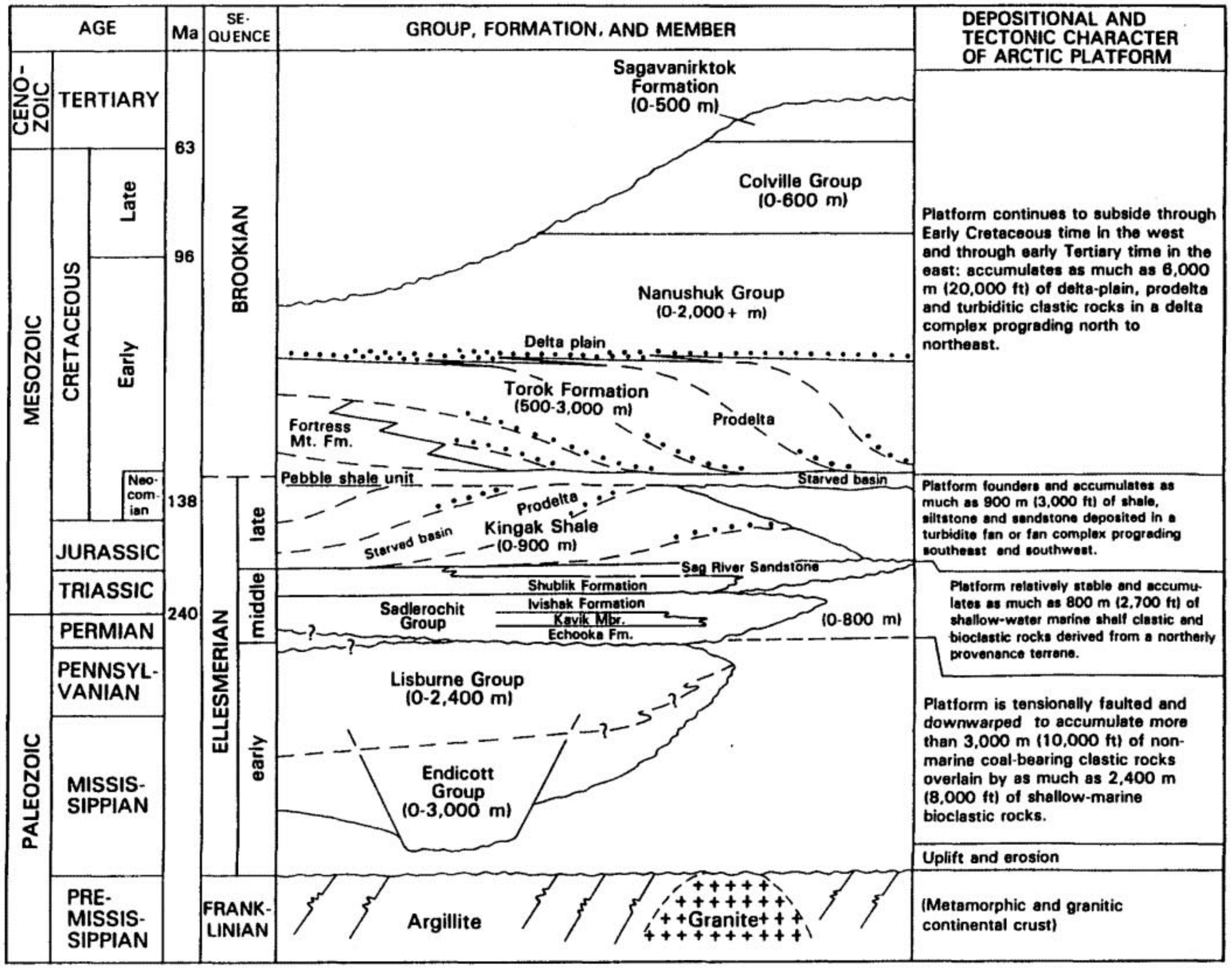
The stratigraphic units (*Figure 4*) most likely to have reservoir potential in the USMA and UCDA are the Torok Formation and the Nanushuk Group. The redefinition (See below.) of the Fortress Mountain Formation, by Molenaar et al. (1988), limits it as a possible reservoir formation to its outcrop belt in the southern part of the USMA.

The USGS, in their assessment of the oil and gas potential of the NPRA, identified the Lisburne Group and Pre-Lisburne rocks as a hydrocarbon play (Bird, 1988b) beneath the USMA and UCDA. Bird (1988c) shows that the Lisburne Group is buried 20,000 feet and more beneath the USMA and UCDA. These rocks may be buried too deeply beneath the Utukok area to warrant consideration for exploration and production even if natural gas from Alaska's North Slope becomes economically viable. But, the carbonates of the Lisburne group could, nonetheless, have good reservoir characteristics.

Other stratigraphic units, below the Torok Formation or the Fortress Mountain Formation, which may have the potential as hydrocarbon reservoirs in other parts of the NPRA, here appear too deeply buried to warrant consideration or, indeed, may not exist beneath the Utukok area. These units include the Sag River Sandstone, the Shublik Formation, and the Sadlerochit Group, all of which lie beneath the "pebble shale" which lies beneath the Torok Formation. The Tunalik Test Well No. 1 drilled into the "pebble shale" unit at a depth of 10,632 feet (Husky Oil NPR Operations, Inc., 1983). Seismic surveys show that the "pebble shale" increases in depth to the south. Magoon and Bird (1988) project that the "pebble shale" unit lies at a depth of about 25,000 feet below the surface at the Awuna site.

In addition to their depth of burial, other factors argue against consideration of these units as potential reservoirs. The Ivishak Formation, of the Sadlerochit Group, and the Sag River Sandstone may not extend beneath the UCDA and USMA. Bird (1988c) shows the Sag River Sandstone at an estimated thickness of only 50 feet under the

Figure 4. Stratigraphy.



Generalized stratigraphy in National Petroleum Reserve in Alaska. Environments of deposition indicated for selected units. Lines of dots diagrammatically show location of some sandstone facies; dashed lines show progradation of deltas.

northern part of the UCDA and USMA. These formations were derived from a northern source area and are prominent in the subsurface along the Barrow trend, they decrease in grain size southward and may be replaced by shale equivalents, and they do not crop out in the Brooks Range to the south of the USMA. The Shublik Formation generally has poor reservoir qualities even in wells where it has oil and gas shows. The reservoir qualities of the Shublik are unlikely to improve at depth beneath the USMA and UCDA.

The Fortress Mountain Formation consists of a thick sequence of sandstone, conglomerate, and shale, geographically limited, for this report and following Molenaar et al. (1988), to its outcrop belt in the southern foothills physiographic province and in the Brooks Range, that is, in the southern USMA. Shale dominates the lithology of the Fortress Mountain Formation, but sandstones and conglomerates occur in thick-bedded, massive units. The sandstones contain a high percentage of lithic grains, and visual and petrographic examination indicate very poor reservoir potential. Clay, resulting from alteration of the lithic fragments, largely fills the pore spaces. Published porosities are generally less than 10 percent. Porosities from surface samples may not reflect porosities in the subsurface, but porosity determinations for the Fortress Mountain Formation in the subsurface are not available. Molenaar et al. (1988) report the occurrence of solid-hydrocarbon dikes in some Fortress Mountain Formation outcrops. Most of these dikes occur in shales. Some cut across sandstones, but in no instance are these sandstones oil stained.

At the surface in the southern foothills, the Torok Formation interfingers with and stratigraphically overlies the Fortress Mountain Formation (Molenaar et al., 1988). The Torok consists mainly of shales with a minor percentage of interbedded, thin sandstones and conglomerates. The sandstones of this interval are generally less than 10 feet thick and generally have porosities less than 10 percent (Molenaar et al., 1988). The Awuna well, however, penetrated sandstones several tens of feet thick below a depth of 8,000 feet. This indicates some potential for relatively thick sandstone intervals which could serve as hydrocarbon reservoirs in the lower part of the Torok Formation. The lower part of the Torok in the Awuna well may be equivalent to the Fortress Mountain Formation exposed in outcrop to the south.

The Nanushuk Group holds the most promise for having reservoir quality rocks within the USMA, but the chances of having a sufficient quantity of porous rock in a favorable structural setting are low. Within the Utukok area, the Nanushuk Group, which crops out at the surface, may reach a thickness of 4,500 feet--its approximate thickness in the Kaolak test well. The sandstone content of the Nanushuk group is low, and the individual sandstone units are usually thin. Chapman and Sable (1960) mapped two formations in the Nanushuk Group, the Kukpowruk Formation, a marine facies deposit, and the overlying Corwin Formation, a nonmarine facies deposit.

Chapman and Sable's (1960) Kukpowruk Formation, which may be 2,000 to 3,000 feet thick in the Utukok area, consists mainly of 65 to 80 percent marine shales and siltstones, and 20 to 35 percent marine sandstones and conglomerates. In the Kaolak test well, the sandstones and conglomerates make up only about 10 percent of the 2,150 foot section which is most likely equivalent to the Kukpowruk. The sandstones occur in beds up to 20 feet thick and in sets of beds up to 100 feet thick. The siltstones and sandstones are usually very hard, i.e. well indurated, and have low porosity.

Chapman and Sable's (1960) Corwin Formation, which overlies and interfingers with the Kukpowruk Formation, consists of nonmarine sandstone, conglomerate, siltstone, shale, coal, coaly shale, and abundant ironstone. Sandstones are lenticular and have extensive shale interbeds (Bartsch-Winkler and Huffman, 1988). In measured sections, sandstone, siltstone, conglomeratic sandstone, and conglomerate, in beds more than 5 feet thick, constitute up to 25 percent of the formation. Thin-bedded sandstones and siltstones occur in interbedded units up to 90 feet thick. In the Kaolak well, one sandstone section is about 170 feet thick (Collins, 1958). The sandstones and siltstones range from very hard to friable, which indicates that porosities probably range from negligible (less than 5 percent) to at least good (15 to 20 percent) (Hyne, 1984).

Fine-grained sedarenites (sandstone composed of sedimentary rock fragments) make up the sandstones of the Corwin Formation. The diagenesis of sedarenites often degrades reservoir quality. Bartsch-Winkler and Huffman (1988) found an average visible porosity of 1.4 percent, an average effective porosity of 8.4 percent, and average air permeability of 14.0 millidarcies. Primary and secondary clays generally clog the interstices, and sparry calcite tightly cements much of the sandstone (Huffman, 1979; Bartsch-Winkler, 1979; Huffman et al., 1988; Bartsch-Winkler and Huffman, 1988). While a sandstone may have locally preserved good primary porosity or developed good secondary porosity, the low percentage of sandstone within the formation and the prevalence of low porosity would make it difficult to locate such an occurrence within the Nanushuk Group.

5. Source Rock Potential and Geochemistry

Several potential source rocks underlie the USMA and UCDA: the Shublik Formation; the Kingak Shale; the "pebble shale;" the Fortress Mountain Formation; the Torok Formation; and the Nanushuk Group.

Of necessity, most of the evidence for the hydrocarbon potential of the Utukok area comes from the nearby wells: the Awuna Test Well No. 1, the Kaolak Test Well 1, the Meade Test Well 1, and the Tunalik Test Well No. 1.

Carter et al. (1977) report the rocks of the Brooks Range, present along the southern border of the USMA, as post-mature for hydrocarbon generation and probably gas prone. The rocks of this province have little potential for having preserved any hydrocarbons that they may have once held.

The Shublik Formation, the Kingak Shale, and the "pebble shale" lie deeply buried beneath the UCDA and the USMA, more than 16,000 feet, and were not penetrated by the nearby Meade, Kaolak, and Awuna wells. They were penetrated by the Tunalik well where the "pebble shale" lies buried to a depth of about 10,600 feet. The Kingak Shale and Shublik Formation lie below the "pebble shale." At the relatively shallow depth in the Tunalik well, the "pebble shale" lies near the base of the organic-carbon maturity zone, based on vitrinite reflectance (R_0=1.6 - 2.1 percent). Most of the organic carbon of the "pebble shale," at the Tunalik site, has been converted to hydrocarbons. The organic carbon of the Kingak Shale and Shublik Formation are post-mature (Claypool and Magoon, 1988). Hydrocarbons generated by these potential source rocks as they passed through the hydrocarbon-generation zone could have migrated into reservoirs in the overlying rocks. Such migrated hydrocarbons could still reside within the hydrocarbon-preservation zone beneath the UCDA and the USMA.

Magoon et al. (1988) show that gas-prone woody kerogen and non-petroleum-prone kerogen (inertinite) predominates in the penetrated sections of all four nearby wells, with the exception of the relatively more organic-rich "pebble shale" in the Tunalik well. The more oil-prone herbaceous kerogen contributes a significant percentage to total kerogen, but the low organic carbon content renders the herbaceous portion insignificant. Oil-prone amorphous kerogen contributes an even less significant percentage to total kerogen.

No NPRA wells penetrate the Fortress Mountain Formation, so all information on its organic geochemistry comes from its outcrops in the southern foothills and Brooks Range. Molenaar et al. (1988) report the Fortress Mountain Formation as a fair source rock for hydrocarbons as 22 samples have 0.45 to 1.40 weight percent organic carbon with a predominance of herbaceous and amorphous kerogen. Vitrinite reflectance values of 0.45 to 1.10, with an average value of 0.65 places the Fortress Mountain within the mature range for hydrocarbon generation.

Although the Torok Formation is thermally mature for the generation of liquid hydrocarbons, based on vitrinite reflectance data, just below the surface in the Awuna well, the formation has unfavorable characteristics as a generator of liquid hydrocarbons. The base for the oil-condensate zone is at a depth of 7,500, feet based on vitrinite reflectance (R_o=1.75 percent); and the bottom of the oil window is 6,500 feet, based on the gas wetness values. This puts more than half of the section penetrated by the Awuna well within the liquid hydrocarbon window. But, the Torok has a low organic-carbon content, 0.5 to 1 weight percent, throughout most of the section penetrated; and the kerogen hydrogen/carbon (H/C) ratio of 0.8 or less and the pyrolitic hydrocarbon/organic carbon ratio o 0.1 or less indicate that the organic carbon has a low capacity for generating liquid hydrocarbons (Claypool and Magoon, 1988).

The Torok Formation in the Kaolak well has a poor potential as a hydrocarbon source rock. The sedimentary section in the well reaches thermal maturity (R_o=0.6 percent) at a depth of 2,000 feet; and at total well depth reaches a value of about 1.2 to 1.3 percent. This places the Torok Formation within the thermally mature zone. The organic-carbon content, however, has low values of about 0.5 to 0.8 percent except where coal beds are present or where a few Torok shale intervals contain as much as 1.5 to 2 weight percent. Kerogen H/C ratios of 0.8 or less and pyrolitic hydrocarbon/organic carbon ratios of 0.15 or less indicate that the organic matter has a low hydrogen content (Claypool and Magoon, 1988).

The Tunalik well has thermally immature organic matter in the Nanushuk Group to a depth of about 3,500 feet, as indicated by vitrinite reflectance data (R_o < 0.6 percent) and gas-wetness values of less than 25 percent. The lower part of the Nanushuk Group and the Torok Formation, from a depth of about 3,500 feet to about 10,000 feet, have a level of maturity required for hydrocarbon generation (0.6 percent < R_o <1.3 percent). Below 12,000 feet, the rocks have a thermal maturity (vitrinite reflectance values greater than 2.2 percent and gas wetness values less than 25 percent) that is not conducive to the preservation of liquid hydrocarbons. The rocks of the Nanushuk and the Torok generally have an organic carbon content of less than 1.0 percent. The organic matter generally is deficient in hydrogen with kerogen H/C ratios of less than 1.0 and pyrolitic HC/OC of 0.15 percent or less. (Claypool and Magoon, 1988).

The hydrocarbon potential for the Torok in the Meade well, somewhat farther afield from the Utukok area, has about the same potential as does the Kaolak well (Claypool and Magoon, 1988).

The hydrocarbon potential for the Nanushuk Group in the Kaolak and Meade wells closely follows that of the Torok Formation according to Claypool and Magoon (1988). So, the Nanushuk has the same poor source-rock potential as does the Torok.

6. Potential of Tetra Tech Utukok Mapped Structures

The permissively contoured (e.g., prospects inferred with minimal sustaining data) Tetra Tech mapped UCDA prospects have potential pay areas ranging from less than 2,000 acres to 100,000 acres.[1] An evaluation, incorporating risk, of hypothetical recoverable reserves from these Tetra Tech mapped prospects within the UCDA yields mean recoverable reserves comparable to sensible extrapolations of the USGS 1988 NSHA. The largest identified prospect, 69,000 acres (mean area) on the Shublik horizon, occurs at a depth of about 19,000 feet (see Appendix B). However, the NPRA oil floor (i.e., depth below which oil is thermally destroyed; using criteria from Hunt, 1979) is thought to be -14,000 to -15,000 ft (geothermal gradient of 15.5_F/1,000 feet); therefore, the structure only has gas potential (about 0.27 TCF, F_{95}=0.035 TCF, F_{05}=0.82 TCF). The largest single possible oil accumulation, 12 mmb (F_{95}=1.3 MMB, F_{05}=32.4 MMB), is mapped in Nanushuk Group horizons ranging from 3,000 to 5,000 feet below the surface. Refined prospect maps based on additional, yet to be acquired, seismic data will likely shrink these potential traps as more faults and shorter wavelength anticlines are identified.

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[1] This seems to contradict the 69,000 acre largest prospect listed in Appendix (B). In fact many of the economic model variables, including area, are probability distributions, and the values given are distribution means. The maximum area allowed for the "69,000 acre prospect" is 100,000 acres.

7. Utukok Area Hydrocarbon Potential

Interpretation of the USGS 1988 Alaskan north slope hydrocarbon assessment (NSHA) suggests southwestern NPRA, including UCDA and USMA, is the least hydrocarbon rich part of the NPRA (*Table* 1; *Figure* 5). The Utukok area is relatively more prospective for gas than for oil (*Figure* 6).

Based on the 1988 USGS estimates, the likelihood of the UCDA/USMA containing economically producible hydrocarbons is negligible. The most optimistic (F_{05})[1] USGS based estimate for conventional recoverable hydrocarbons forecasts 598.2 MMBO[2] and 6.7 TCFG[3] in all prospects within the combined UCDA and USMA; F_{95} - 19.4 MMBO and 0.4 TCFG; the means are 185.4 MMBO and 2.3 TCFG (Table 2).[4] Comparable figures for just the UCDA are: F_{05} - 219.3 MMBO and 2.7 TCFG; F_{95} - 4.5 MMBO and 0.08 TCFG; and means of 61.0 MMBO and 0.8 TCFG (*Table* 3). These quantities, even lumping all Utukok's F_{05} oil into one improbable prospect, are, at best, marginally economic[5] under foreseeable market conditions.

Other NPRA regions are deemed more hydrocarbon rich and environmentally less sensitive. Portions of northern, north-eastern, east-central, and south-eastern NPRA, for instance, have greater

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1 That is a 5% chance of at least that amount occurring. F_{95} is interpreted analogously.

2 Million barrels of oil.

3 Trillion cubic feet of gas.

4 These estimates are derived from the USGS 1988 north slope hydrocarbon appraisal by assuming the play resources are distributed equally over the play and then apportioning reserves according to the percentage of the play within Utukok.

5 Young and Hauser (pg.51, 1984; Economics of oil and gas production from ANWR for the determination of minimum economic field size, BLM unpublished report, 68 p.) developed a 575 MMB minimum economic field size (MEFS) for the eastern 1002 area. Utukok is approximately twice as far from the existing oil production and transportation system than is eastern ANWR, suggesting that the Utukok MEFS would be at least as large as eastern ANWR's. More recently, however, Attanasi et al. (in press) developed a 384 MMB base case north slope MEFS. Their analysis cites examples of far lower operating costs (e.g., developing the Kuparuk field for roughly one-third of estimated cost) reflecting both greater competition and knowledge gleaned from north slope operations.

estimated hydrocarbon potential[1] in areas lacking Utukok's documented caribou and grizzly bear habitat (See for example: Record of Decision on oil and gas leasing and development in NPRA, 5/83, BLM, *Fig*. 3).

The best potential for large (i.e., >1,000 MMB) NPRA oil accumulations may be in Ellesmerian strata lapping out on the south flank of the "Barrow arch" in northern NPRA. There, depths to potential hydrocarbon reservoirs are in the oil preservation zone (i.e., ambient temperature below the oil breakdown threshold). Currently, such stratigraphic traps are elusive objectives, typically disclosing, at best, only subtle seismic signs of existence. With luck, future exploration methods will better illuminate key details of stratigraphy upon which the discovery of stratigraphically trapped oil depends. There may be less potential, though, for large NPRA hydrocarbon finds on the highly regarded Barrow high[2] where numerous exploratory wells drilled to economic basement (i.e., pre-Mississippian levels) in north and, notably, northeastern NPRA, areally constrains undiscovered hydrocarbon accumulations.

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1 If the poorest NPRA mean recoverable oil potential is assigned a value of 1, the highest mean potential is 54 (Figure 5). On this scale the best any Utukok area scores is 3. The mean oil potential north of the Utukok ranges from 10 to 39. This rating is based on the USGS 1988 NSHA and the assumption (obviously incorrect) that the mean oil is distributed uniformly over each play; see Appendix (a).

2 The USGS NSHA depicts the Barrow arch as amongst the most oil rich of the remaining north slope petroleum plays.

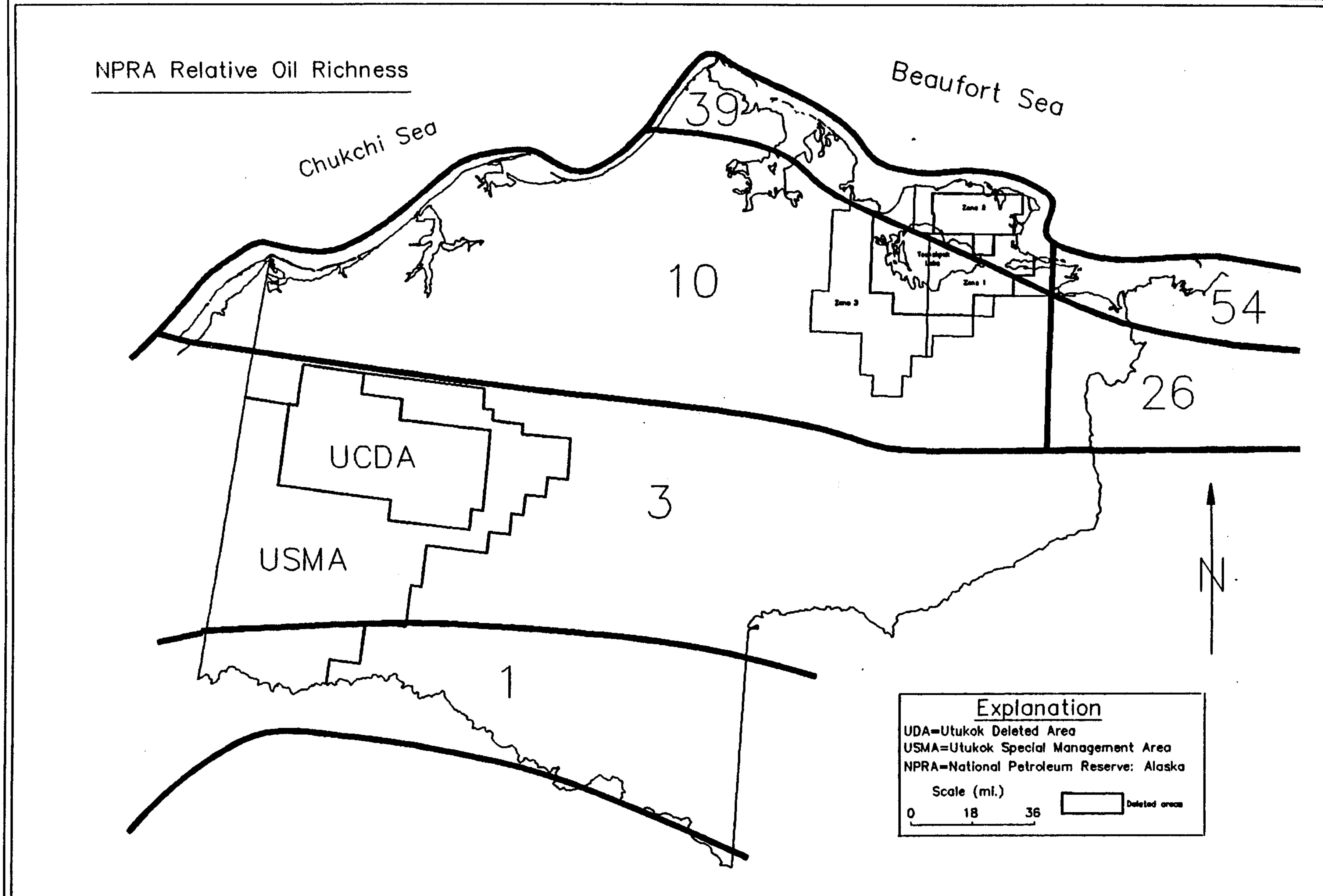

Figure 5. Relative oil richness. (based on USGS 1988 NSHA)

Table 1

Utukok Mean Oil, Gas and Area
as a Percent of NPRA Hydrocarbons and Area*

	% Oil	% Gas	% NPRA
UCDA	3	5	5
UCDA + USMA	7	14	17

Basis: USGS 1988 NSHA and Mast, Bird, and Crovelli, 1991, personal communication.
* NPRA encompasses about 36,000 square miles, and , based on the USGS 1988 NSHA, the estimated mean conventionally recoverable hydrocarbons are 2.6 billion barrels of oil and 16.6 trillion cubic feet of gas.

Table 2

NPRA Utukok Areas*

Estimated Recoverable Hydrocarbons

Area: 3.95 million acres

	Oil (MMB)	Gas (BCF)
Mean	185.4	2316.9
F_{95}	19.4	410.3
F_{05}	598.2	6646.2

Basis: Mast, Bird, and Crovelli, 1991, personal communication.

* The Utukok caribou deleted area and contiguous caribou/grizzly special management area.

Table 3

NPRA Utukok Caribou Deleted Area
Estimated Recoverable Hydrocarbons
Area: 1.198 million acres

	Oil (MMB)	Gas (BCF)
Mean	61.0	802.7
F_{95}	4.5	76.0
F_{05}	219.3	2648.4

Basis: Mast, Bird, and Crovelli, 1991, personal communication.

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Chapter III - Conducting and documenting the analyses of factors

B. Procedural Guidance.

3. Analyze Resource Capability and Potential.

c. Rating and Mapping Potential. As a part of this analysis, a resource potential map should be produced which shows: major geolgic trends; USGS or other published play boundaries or KGRA boundaries; play boundaries for conventional and unconventional oil and gas resources developed by BLM; and areas of high, medium, low or no potential for occurrence and development as outlined below. In rating and mapping potential, include a description of the level of confidence which indicates the approximate accuracy of any boundaries identified (i.e., using standard cartographic techniques).

(1) Oil and Gas. Due to the nearly ubuquitous presence of hydrocarbons in sedimentary rock, use the following for classifying oil and gas potential:

HIGH. Inclusion in an oil and gas play as defined by the USGS national assessment, or, in the absence of a play designation by USGS, the demonstrated existence of: source rock, thermal maturation, and reservoir strata possessing permeability and/or porosity, and traps. Demonstrated existence is defined by physical evidence or documentation in the literature. (Note that reasonable adjustments to any USGS play areas and boundaries may be made if it is apparent that a particular boundary was set up based on administrative convenience rather than a definable change in geological character.)

MEDIUM. Geophysical or geological indications that the following may be present: source rock, thermal maturation, and reservoir strata possessing permeability and/or porosity and traps. Geologic indication is defined by geological inference based on indirect evidence.

LOW. Specific indications that one or more of the following may not be present: source rock, thermal maturation, or reservoir strata possessing permeability and/or porosity, and traps.

NONE. Demonstrated absence of (1) source rock, (2) thermal maturation, or (3) reservoir rock that precludes the occurrence of oil and/or gas. Demonstrated absence is defined by physical evidence or documentation in the literature.

Appendix B

Model: Utukok2.wk1 @Risk

Utukok Deleted Area Assessment   Zhigh Zlow 33 gas program   HR:= horizon risk
Tetra Tech Mapped Prospects   Geothermal gradient 15.5°F/k ft   PR:= prospect risk
Hypothetical Reserves   Gas gravity: >5000 psia = 0.71; <5000 psia = 0.656

Play: pre-Mississippian   MinEcoFldSzOil: 0 mmb Gas: 0 tcf Rf_o= oil rec.   EROil: 0.0 mmb
Trap Fill: 52% Porosity: 8% S_w: 28% Rf_g: 73% P_b: 14.7 psi** Rf_g= gas rec.   ERGas: 0.0 tcf
Net Pay: 60' Rf_o: 0% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	20.0	5undiscovered .0	32500	25.5	3	0.15	0	0.00	1.54	414	12750	0.05	0.00
2	8.0	5.0	13250	26.0	4	0.21	0	0.00	1.55	422	13000	0.03	0.00
3*	7.0	6.5	9300	26.2	2	0.10	0	0.00	1.56	424	13083	0.01	0.00
4	9.0	2.0	6500	30.0	3	0.13	0	0.00	1.64	482	15000	0.01	0.00
5	9.0	3.5	9750	26.5	4	0.21	0	0.00	1.56	429	13250	0.02	0.00
6	11.0	3.0	9500	30.0	1	0.05	0	0.00	1.64	482	15000	0.00	0.00
7	6.0	1.5	3000	26.5	1	0.05	0	0.00	1.56	429	13250	0.00	0.00
8	5.5	1.5	2700	30.0	2	0.10	0	0.00	1.64	482	15000	0.00	0.00

* partially outside UDA; area listed is within the UDA.   MeanOil 0.0 mmb   MeanGas 0.12 tcf

Utukok EIS Deleted Area
Play: Lisburne   MinEcoFldSzOil: 0 mmb Gas: 0 tcf   EROil: 0.0 mmb
Trap Fill: 52% Porosity 8% S_w: 28% Rf_g: 73% P_b: 14.7 psi   ERGas: 0.0 tcf
Net Pay: 60' Rf_o: 0% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	13.0	6.0	24350	23.0	4	0.21	0	0.00	1.47	377	11500	0.05	0.00
2	7.0	3.5	8650	23.0	2	0.10	0	0.00	1.47	377	11500	0.01	0.00
3	4.0	4.0	5675	23.0	2	0.10	0	0.00	1.47	377	11500	0.01	0.00
4	6.0	3.0	5950	23.0	0	0.03	0	0.00	1.47	377	11500	0.00	0.00
5*	7.0	6.0	11350	23.0	3	0.13	0	0.00	1.47	377	11500	0.01	0.00
6	6.0	2.5	5000	23.5	1	0.05	0	0.00	1.48	384	11750	0.00	0.00
7	9.0	3.0	8950	24.0	2	0.10	0	0.00	1.50	392	12000	0.01	0.00
8	10.0	3.0	11900	24.0	3	0.13	0	0.00	1.50	392	12000	0.01	0.00
9	7.0	2.5	10000	24.0	2	0.10	0	0.00	1.50	392	12000	0.01	0.00
10	4.0	1.5	1950	24.0	2	0.10	0	0.00	1.50	392	12000	0.00	0.00

* partially outside UDA; area listed is within the UDA.   MeanOil 0 mmb   MeanGas 0.11 tcf

Utukok EIS Deleted Area
Play: Triassic Shublik   MinEcoFldSzOil: 0 mmb Gas: 0 tcf   EROil: 0.0 mmb
Trap Fill: 52% Porosity: 18% S_w: 28% Rf_g: 73% P_b: 14.7 psi   ERGas: 0.0 tcf
Net Pay: 75' Rf_o: 0% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	23.0	10.5	69300	19.0	9	0.43	0	0.00	1.35	317	9500	0.27	0.00
2	24.0	7.0	43300	19.5	6	0.35	0	0.00	1.37	324	9750	0.14	0.00
3	11.0	4.0	13550	19.5	1	0.05	0	0.00	1.37	324	9750	0.01	0.00
4	6.0	3.5	7250	20.0	2	0.10	0	0.00	1.38	332	10000	0.01	0.00
5	10.0	3.0	10400	19.5	3	0.13	0	0.00	1.37	324	9750	0.01	0.00

MeanOil 0 mmb   MeanGas 0.44 tcf

Utukok EIS Deleted Area

Play: Pebble shale MinEcoFldSzOil: 0 mmb Gas: 0 tcf EROil 0.0 mmb

Trap Fill: 52% Porosity: 11% S_w: 28% Rf_g: 60% P_b: 14.7 psi ERGas 0.0 tcf

Net Pay: 32' Rf_o: 27% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	18.0	2.8	16250	15.5	2	0.10	2	0.00	1.22	264	7750	0.01	0.00
2	10.0	2.0	6225	16.0	2	0.10	1	0.00	1.24	272	8000	0.00	0.00
3*	9.0	2.5	3750	15.5	2	0.10	1	0.00	1.22	264	7750	0.00	0.00
4	6.5	2.0	4350	16.0	2	0.10	1	0.00	1.24	272	8000	0.00	0.00
5	13.0	3.0	12025	15.5	1	0.05	1	0.00	1.22	264	7750	0.00	0.00
6	5.0	2.0	5200	15.0	2	0.10	1	0.00	1.20	257	7500	0.00	0.00
7			4825	14.8	2	0.10	1	0.00	1.20	254	7400	0.00	0.00
8	9.5	2.5	7850	14.5	3	0.13	1	0.00	1.18	249	7250	0.01	0.00
9	14.0	4.0	15225	13.5	5	0.30	6	0.00	1.14	234	6750	0.03	0.00
10	7.0	2.5	6175	13.9	1	0.05	0	0.00	1.14	240	6950	0.00	0.00
11	7.0	1.0	1625	15.3	2	0.10	0	0.00	1.22	261	7650	0.00	0.00
12	13.0	1.0	1875	15.5	3	0.13	0	0.00	1.22	264	7750	0.00	0.00

* partially outside UDA; area listed is within the UDA. MeanOil 15 mmb MeanGas 0.08 tcf

Utuok EIS Deleted Area

Play: L.Cret Fortress Mountain MinEcoFldSzOil: 0 mmb Gas: 0 tcf EROil 0.0 mmb

Trap Fill: 52% Porosity: 15% S_w: 28% Rf_g: 60% P_b: 14.7 psi ERGas 0.0 tcf

Net Pay: 41' Rf_o: 22% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	14.0	1.5	7625	10.0	2	0.10	1	0.00	0.96	182	5000	0.01	0.00
2*	17.0	3.0	7250	6.0	6	0.35	5	0.00	0.79	122	3000	0.01	0.00
3	9.0	3.0	7050	9.5	1	0.05	1	0.00	0.94	174	4750	0.00	0.00
4	4.0	1.0	1350	8.5	3	0.13	0	0.00	0.90	159	4250	0.00	0.00
5	6.5	1.0	1735	9.0	0	0.03	0	0.00	0.92	167	4500	0.00	0.00

* partially outside UDA; area listed is within the UDA. MeanOil 7 mmb MeanGas 0.02 tcf

Utuok EIS Deleted Area

Play: Shallow Cret Nanushuk Group MinEcoFldSzOil: 0 mmb Gas: 0 tcf — EROil 0.0 mmb

Trap Fill: 52% Porosity: 14% S_w: 28% Rf_g: 60% P_b: 14.7 psi — ERGas 0.0 tcf

Net Pay: 42' Rf_o: 22% T_b: 32°F HR: 0.5

Prospect	L mi	W mi	Area a	Depth k'	#Lines	PR	mmbo	ero	Z	T_f	P_f	GR tcf	erg
1	15.0	2.5	9925	4.5	4	0.21	4	0.00	0.74	99	2250	0.01	0.00
2	26.0	3.0	11300	5.0	4	0.21	4	0.00	0.76	107	2500	0.01	0.00
3	20.0	2.0	13800	2.0	5	0.30	8	0.00	0.79	62	1000	0.01	0.00
4	14.0	4.0	18525	3.6	1	0.05	2	0.00	0.73	86	1800	0.00	0.00
5	19.0	3.0	18650	2.8	6	0.35	12	0.00	0.75	74	1400	0.02	0.00
6	9.0	4.0	11925	1.0	2	0.10	2	0.00	0.88	47	500	0.00	0.00
7	9.0	1.0	2980	1.0	1	0.05	0	0.00	0.88	47	500	0.00	0.00
8	8.0	2.0	5250	3.5	3	0.13	1	0.00	0.73	84	1750	0.00	0.00
9	12.0	1.0	3950	1.0	2	0.10	1	0.00	0.88	47	500	0.00	0.00
10	8.0	2.0	5250	4.0	1	0.05	0	0.00	0.74	92	2000	0.00	0.00
11	5.0	1.0	1680	5.0	1	0.05	0	0.00	0.76	107	2500	0.00	0.00
12*	20.0	2.0	6600	3.2	4	0.21	3	0.00	0.74	80	1600	0.00	0.00

* partially outside UDA; area listed is within the UDA. MeanOil 37 mmb MeanGas 0.06 tcf

Total oil: 60 mmb Total gas: 0.83 tcf

Total ER Oil: 0 mmb Total ER Gas: 0.00 tcf

** P_b and T_b= NPRA surface pressure and temperature respectively; P_f and T_f = estimated pressure and temperature respectively at prospect depth; Z = gas compressibility factor; Rf_o= 0 for the pre-Mississippian, Lisburne, and Shublik plays because depths to these prospects (19,000'+) suggest ambient temperatures (>327°F) incompatible with appreciable oil preservation.