Mineral Occurrence and Development Potential Report

LEASABLE MINERALS

Kobuk - Seward Peninsula
Resource Management Plan

BLM Alaska State Office
Division of Energy and Solid Minerals
Branch of Energy
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Mineral Occurrence and Development Potential Report (MODPR) for Leasable Minerals

List of Acronyms

ADNR	- Alaska Department of Natural Resources
AFO	- Anchorage Field Office
ASRC	- Arctic Slope Regional Corporation
Bcf	- Billion Cubic Feet
BLM	- Bureau of Land Management
CBNG	- Coalbed Natural Gas
CFR	- Code of Federal Regulations
DGGS	- Department of Geological and Geophysical Survey
DOE	- Department of Energy
DOT&PF	- Department of Transportation and Public Facilities
EIS	- Environmental Impact Statement
IRP	- Industrial Roads Program
KGRA	- Known Geothermal Resource Area
KSP	- Kobuk-Seward Peninsula
LMP	- Leasable Mineral Potential
Ma	- Million years ago
MODPR	- Mineral Occurrence and Development Potential Report
Mmb	- Million Barrels
NFO	- Northern Field Office
NPRA	- National Petroleum Reserve in Alaska
NWR	- National Wildlife Refuge
RFD	- Reasonable Foreseeable Development Scenario
RMP	- Resource Management Plan
RTA	- Resource Transportation Analysis
Tcf	- Trillion Cubic Feet
VLF	- Very Low Frequency

I. INTRODUCTION

A. Purpose of Report

This Mineral Occurrence and Development Potential Report (MODPR) was prepared to assure the availability and consideration of leasable mineral resources data during the Kobuk-Seward Peninsula (KSP) Resource Management Plan (RMP) process. The MODPR provides an intermediate level of detail for mineral assessments as prescribed in the 1985 BLM Manual Sections 3031 (Energy and Mineral Resource Assessment) and 3060 (Mineral Reports – Preparation and Review). Information provided in the report will be incorporated into the RMP and the Environmental Impact Statement (EIS).

This report provides a geologic description of the area comprising the RMP including subsections on physiography, stratigraphy, structural geology, historical geology, and geophysical and geochemical data. In addition, the report describes the leasable mineral resources present in the Planning Area and includes a discussion of the occurrence and development potential over the 15-year planning period. This report is not a decision document, and does not present specific recommendations as to which lands should be open for mineral leases, or which (if any) lease stipulations should be modified. Specific recommendations concerning land use planning issues will be included in the RMP/EIS.

Identified fluid leasable minerals (including oil, gas, geothermal, and coalbed natural gas) resources are classified according to BLM Handbook H-1624-1, Planning for Fluid Mineral Resources. BLM Manual 3031 specifies that minerals be classified according to mineral potential (utilized to rank the potential for presence or occurrence, as opposed to the potential for development or extraction). This classification system rates potential for the occurrence of mineral resources in categories of High (H), Moderate (M), Low (L), Very Low (V), and no potential (O). The classification is followed by a rating of the level of certainty of the data ranging from A to D, indicating degrees of confidence in the evidence regarding the presence of a particular mineral occurrence. A D rating indicates the least amount of data available, while an A rating indicates a high degree of data available (Table 1).

Table 1: Rating System for Leasable Minerals Occurrence Potential in the KSP Planning Area

Mineral	Occurrence Classification
Oil	H/B
Natural Gas	H/B
Coalbed natural gas	H/C
Coal	H/A
Oil Shale	O/D
Phosphate	O/D
Sodium	O/D
Geothermal	M/C

Fluid mineral occurrence and development potential in the KSP Planning Area is primarily associated with coal, and coalbed natural gas (CBNG), oil and gas, and geothermal. Oil shale, phosphates, and sodium were not analyzed as there is no existing data for these resources in the planning area.

As described in BLM Manual H-1624-1, federal oil and gas leases (including coal bed methane) fall into one of four categories that become increasingly restrictive (BLM, 1986):

1. Open Subject to Standard Lease Terms and Conditions: These are areas where it has been determined through the planning process that the terms and conditions attached to the leasing document are sufficient in allowing exploration and development.
2. Open Subject to Seasonal or Other Minor Constraints: These are areas where it has been determined that moderately restrictive lease stipulations may be required to mitigate impacts to other land uses or resource values. Category 2 leases frequently involve timing limitations such as restricting construction activities in designated Big Game Winter Ranges, or controlled surface use stipulations such as creating a buffer zone around a critical resource.
3. Open Subject to No Surface Occupancy or Other Major Constraint: These are areas where it has been determined through the planning process that highly restrictive lease stipulations are necessary to protect resources. Category 3 leases may prohibit the construction of well production and support facilities. These areas can be subject to directional drilling.
4. Closed to Leasing: These are areas where it has been determined that other land uses or resource values cannot be adequately protected, and appropriate protection can only be ensured by closing the land to leasing through either statutory or administrative requirements. These areas are outlined in 43 CFR 3100.

These areas are identified and mapped in the RMP document.

B. Lands Involved

The Kobuk – Seward Peninsula Planning Area encompasses 31.6 million acres in northwestern Alaska. The BLM Northern Field Office (NFO) manages 13 million acres of public land and over 13 million acres of federal mineral estate within the KSP RMP (Table 2). Additional land managers within the RMP boundary include three Native Corporations, the State of Alaska, U.S. Fish and Wildlife Service, and the National Park Service (Table 3). The largest communities are Kotzebue and Nome with populations of 3,000 and 5,000, respectively.

Table 2: Breakdown of BLM-Managed Lands in the Planning Area

Land Category	
BLM Public Lands (Unencumbered)	4,990,000
State Selected (BLM)	3,568,000
AK Native Claims Settlement Act (ANCSA) Selected (BLM)	4,419,000
Both State & ANCSA Selected	109,000
Total BLM	**13,086,000**

*Note: All acreage figures are rounded to the nearest 1,000 acres

Table 3: Breakdown of Non-BLM Lands in the Planning Area

Land Category	Total Acres
National Park Service Lands	4,222,000
Fish and Wildlife Service Lands	2,978,000
State of Alaska Lands	5,635,000
Native (ANCSA) Lands	5,596,000
Private	233,000
Military	20,000
Total Non-BLM	**18,684,000**

*Note: All acreage figures are rounded to the nearest 1,000 acres

C. Scope and Objectives

This MODPR describes the known, existing mineral resources and current resource management in the planning area, and identifies areas of High, Moderate, Low, and Very Low mineral potential. By incorporating a wide variety of available geologic information, including State and Federal reports, the minerals report will present a summary of development potential for the entire KSP Planning Area, regardless of land status. This assessment provides an intermediate level of detail, as required by Manual Section 3031 for all BLM land use plans.

Information contained in this report will be used to prepare a Reasonably Foreseeable Development Scenario Report (RFD). This report will focus on the type, location, and manner of potential environmental disturbances due to leasable minerals exploration, development and production.

II. DESCRIPTION OF GEOLOGY

A. Physiography

The KSP Planning Area includes terrain ranging from coastal lowlands to mountainous regions with greater than 3,000 feet of local relief (Wahrhaftig 1965). Continuous permafrost underlies the majority of the planning area to an estimated depth of 1,000 feet. This irregular land surface or thermokarst topography, and other cryogenic processes present within the planning area include; tussock tundra, thaw lakes, ice-cored mounds (pingos), and patterned (polygonal) ground. The permafrost in this region has an active layer exhibiting seasonal thaw up to 4 feet. Wahrhaftig's description of Alaska's physiographic provinces (Figure 1) remains the authoritative reference, portions of which are described below.

Arctic Coastal Plain

The Arctic Coastal Plain extends south from the Arctic Ocean, rising gradually to a maximum elevation of 600 feet. The smooth plain is underlain by permafrost and ubiquitous permafrost landforms. The area is poorly drained, with numerous lakes and marshy areas. A scarp 50 to 200 feet tall locally separates the Arctic Coastal Plain from the Arctic Foothills Province to the south. The Coastal Plain is underlain by Quaternary to Tertiary sedimentary units.

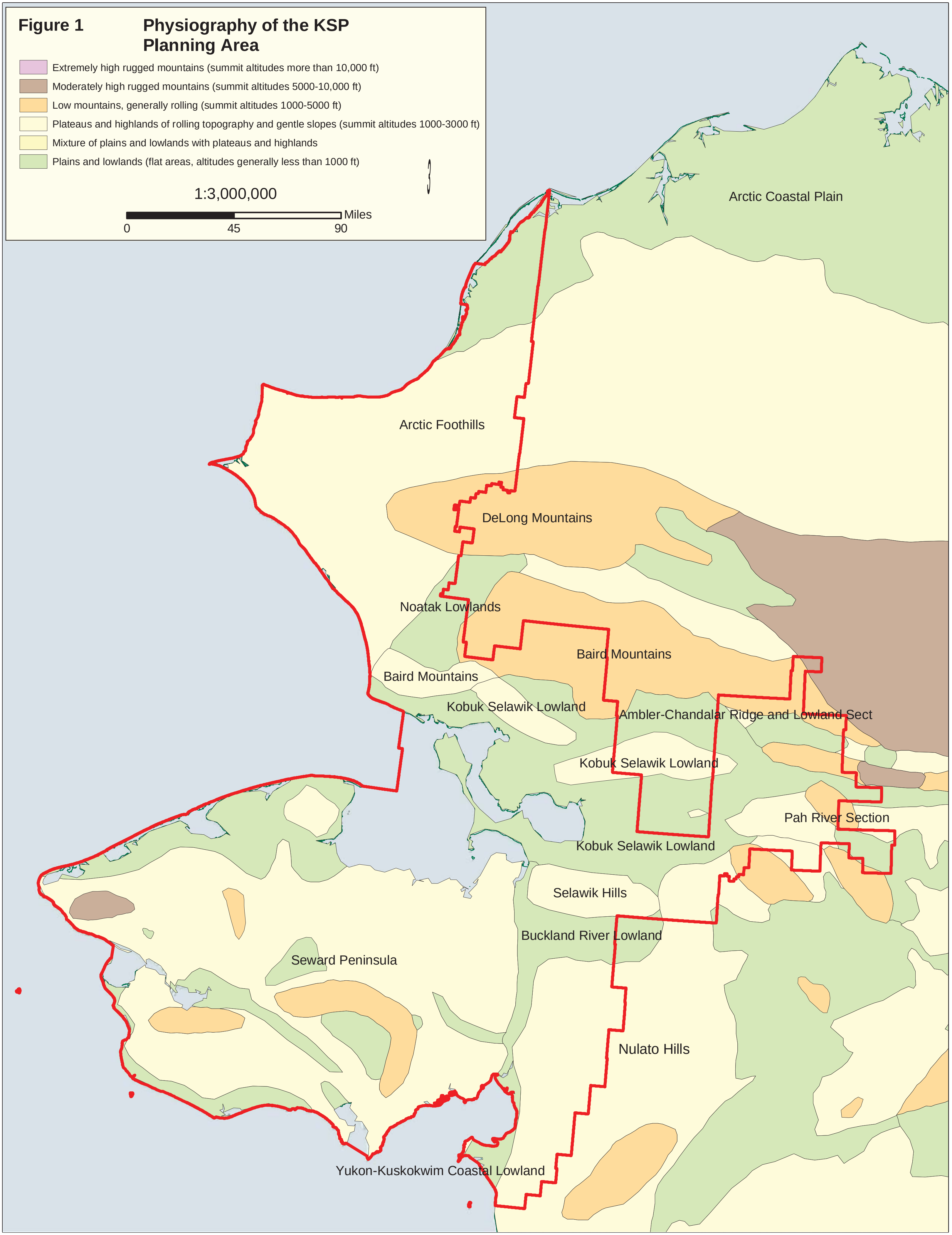
Figure 1
Physiography of the KSP Planning Area
Extremely high rugged mountains (summit altitudes more than 10,000 ft)
Moderately high rugged mountains (summit altitudes 5000-10,000 ft)
Low mountains, generally rolling (summit altitudes 1000-5000 ft)
Plateaus and highlands of rolling topography and gentle slopes (summit altitudes 1000-3000 ft)
Mixture of plains and lowlands with plateaus and highlands
Plains and lowlands (flat areas, altitudes generally less than 1000 ft)
1:3,000,000
Miles
0
45
90
Arctic Coastal Plain
Arctic Foothills
DeLong Mountains
Noatak Lowlands
Baird Mountains
Baird Mountains
Kobuk Selawik Lowland
Ambler-Chandalar Ridge and Lowland Sect
Kobuk Selawik Lowland
Pah River Section
Kobuk Selawik Lowland
Selawik Hills
Buckland River Lowland
Seward Peninsula
Nulato Hills
Yukon-Kuskokwim Coastal Lowland

Arctic Foothills

The Arctic Foothills occupies the area between the Arctic Coastal Plain and the area north and west of the Western Brooks Range. Rolling plateaus and low linear mountains rise from 600 feet in the north to over 3,000 feet in the south. Upland tundra plateaus are typically dissected by north-flowing braided streams. Although not covered by glaciers, the area is entirely underlain by permafrost and exhibits frozen ground morphologies. Foothills Province bedrock consists of Quaternary to Devonian sedimentary units and mafic intrusives, with structural over-thrusting to the north.

Arctic Mountains (Western Brooks Range)

The Baird and DeLong Mountains, and an intervening lowland occupied by the Noatak River, comprise the Arctic Mountains physiographic province in the KSP Planning Area. Sharp, glaciated peaks in mountainous areas rise abruptly to 2,500 to 4,500 feet and are cored by Paleozoic metasediments (Baird Mountains) and Devonian to Cretaceous sediments (DeLong Mountains). Massive diabase dikes intrude the DeLong Mountains and are prominent cliff-forming features. Structural trends are predominantly east-west to northeast-southwest. The Noatak River valley and adjacent rolling uplands host numerous morainal and thaw lakes. Primary drainage for the province is via the south-flowing Noatak River; the south slopes of the Baird Mountains drain into the Kobuk River.

A small area near Ambler and Kobuk in the eastern portion of the KSP Planning Area is covered by intensely glaciated ridges along the abrupt southern front of the Brooks Range. Ridges in the Ambler area are composed of Mesozoic greenstone (metamorphosed basalts). The intervening valleys are underlain by folded Cretaceous sediments.

Bering Shelf

The Bering Shelf Province occupies a limited, less than 250,000 acre, portion of the KSP Planning Area adjacent to the coastal village of Shaktoolik on Norton Sound. The Bering Shelf is extensively covered by Quaternary sand and silt. Local bedrock exposures range from Cretaceous and Tertiary volcanic units (chiefly basalts) to older Paleozoic crystalline rocks. The Bering Shelf, along with the Seward Peninsula and Western Alaska Provinces, was part of the ice-free Beringia Corridor that connected Alaska to Northeast Asia during the last Ice-age.

Seward Peninsula

The entire Seward Peninsula Province lies within the Seward Peninsula, and as such represents the largest areal portion of the KSP Planning Area. The Seward Peninsula Province is approximately 200 miles wide in an east-west direction, 140 miles long in a north-south direction, and is bordered on the west by the Bering Strait and on the east by the Western Alaska Province. The Seward Peninsula Province consists of an extensive upland area with interior basins and coastal lowlands. The uplands portion ranges from broad-sloping hills up to 2,000 feet in elevation; isolated groups of glaciated peaks below 4,700 feet in elevation are concentrated in the south. Interior basins are drained through narrow canyons which cut the uplands, transitioning into meandering streams which cross the lowlands to the ocean. Paleozoic bedrock is predominant on the Seward Peninsula, consisting of metasediments and metamorphosed volcanic rocks, all cut by younger granitic intrusives. Quaternary lava flows occupy the north-central portion of the Seward Peninsula.

Western Alaska
The Western Alaska Province covers the southeast-quarter of the KSP Planning Area. The province is dominated by the Kobuk-Selawik Lowlands, the Nulato Hills, and numerous smaller lowland and hill areas. Most of the area drains into Kotzebue Sound via the Kobuk and Selawik Rivers, although streams draining the western slopes of the Nulato Hills discharge into Norton Sound. Thaw lakes are common in lowland areas. Local relief in the Nulato Hills area is 500 to 1,500 feet, with peaks reaching 2,500 feet in elevation. Most of these low, rolling hills have been spared from recent glaciations and were part of the ice-free Beringia corridor linking North America and Asia. The Nulato Hills is cored by tightly folded Cretaceous sediments and minor volcanics. The Selawik Hills, which rise abruptly from the Kobuk-Selawik Lowlands to as much as 3,300 feet in elevation, have gently sloping to flat summits. Geology in the Selawik Hills is typified by Paleozoic and Mesozoic metavolcanic and granitic rocks.

B. Rock Units (Lithology and Stratigraphy)

This section presents a summary of rock units in the Kobuk-Seward Peninsula planning area listed chronologically from oldest to youngest. Figure 2 (from the locatable mineral MODPR) presents a generalized geologic map for the KSP Planning Area after Beikman (1980). It should be noted that many mapped geologic units in the KSP Planning Area remain unnamed.

Basement Rocks
Crystalline basement lithologies occur near the surface across a wide swath of the Seward Peninsula and in the western Brooks Range. On the Seward Peninsula, the pre-Mississippian bedrock consist of blueschist-, greenschist-, and amphibolite-facies schist, phyllite, and marble (Till and Dumoulin, 1994). The southern flank of the Brooks Range and Baird Mountains comprises a structurally complex thrust and fold package of metamorphosed marine shelf sediments (blueschist), which are likely correlative to basement rocks found on the Seward Peninsula based on similar age and lithology. Jurassic- to Mississippian-age ophiolites are mapped in the Southern Brooks Range (Angayucham Terrane), in the western Delong Mountains (Asik Mountain), and western Baird Mountains (Iyikrok Mountain). These mafic-ultramafic assemblages occur chiefly as pillow-basalt (greenstone), chert, diabase, and gabbro, with local interbedded clastic marine sediments.

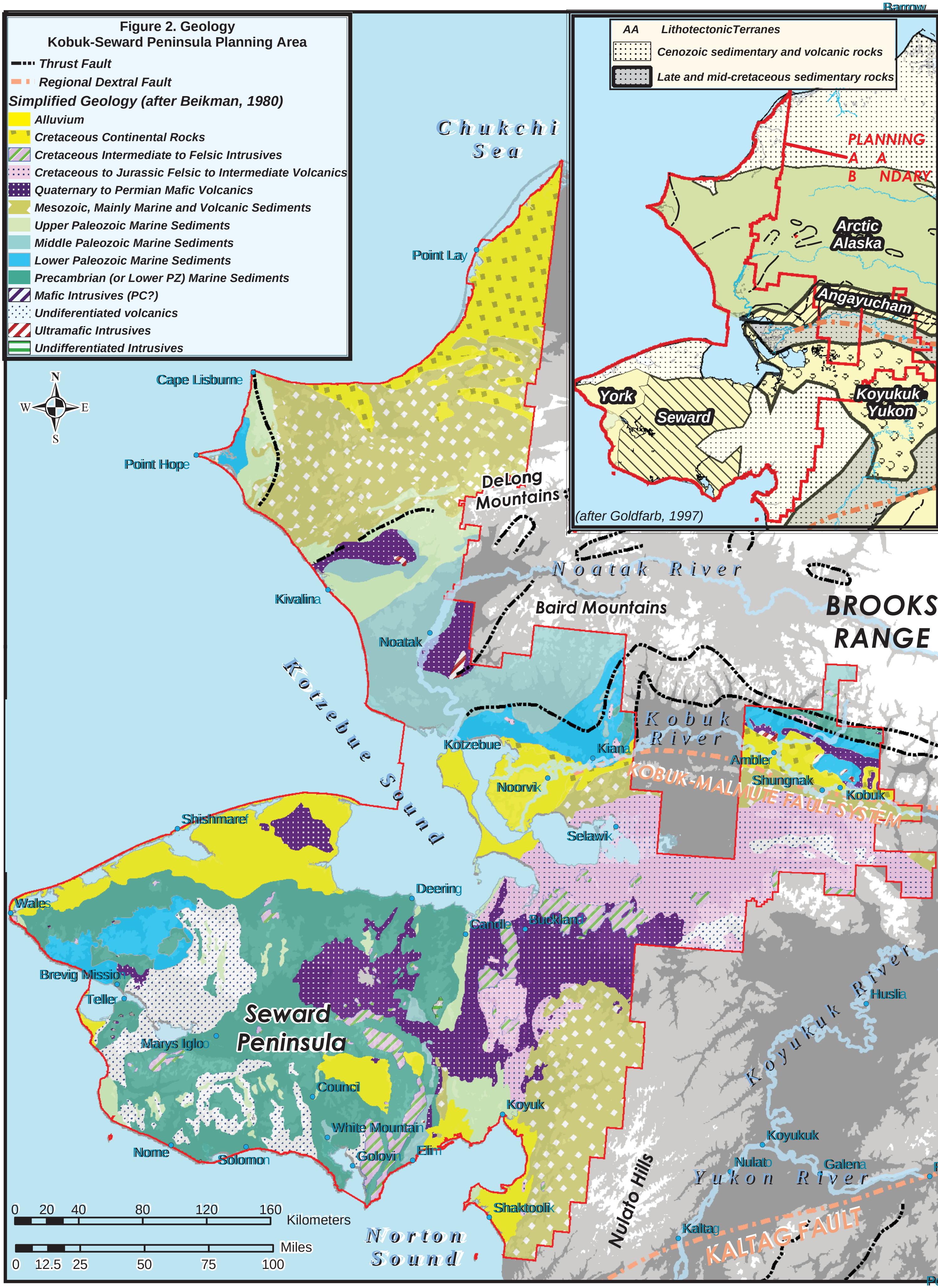

Figure 2. Geology
Kobuk-Seward Peninsula Planning Area
Thrust Fault
Regional Dextral Fault
Simplified Geology (after Beikman, 1980)
Alluvium
Cretaceous Continental Rocks
Cretaceous Intermediate to Felsic Intrusives
Cretaceous to Jurassic Felsic to Intermediate Volcanics
Quaternary to Permian Mafic Volcanics
Mesozoic, Mainly Marine and Volcanic Sediments
Upper Paleozoic Marine Sediments
Middle Paleozoic Marine Sediments
Lower Paleozoic Marine Sediments
Precambrian (or Lower PZ) Marine Sediments
Mafic Intrusives (PC?)
Undiferentiated volcanics
Ultramafic Intrusives
Undifferentiated Intrusives
AA Lithotectonic Terranes
Cenozoic sedimentary and volcanic rocks
Late and mid-cretaceous sedimentary rocks
PLANNING A A B NDARY
Arctic Alaska
Angayucham
York
Seward
Koyukuk Yukon
(after Goldfarb, 1997)
Barrow
Chukchi Sea
Point Lay
Cape Lisburne
Point Hope
DeLong Mountains
Noatak River
Baird Mountains
BROOKS RANGE
Kivalina
Noatak
Kotzebue Sound
Kotzebue
Kiana
Kobuk River
Ambler
Shungnak
Kobuk
KOBUK-MALMUTE FAULT SYSTEM
Noorvik
Selawik
Shishmaref
Wales
Deering
Candle
Buckland
Brevig Missio
Teller
Seward Peninsula
Marys Iglo
Counci
Koyuk
White Mountain
Nome
Solomon
Golovin
Elim
Shaktoolik
Koyukuk River
Huslia
Koyukuk
Nulato
Galena
Yukon River
Nulato Hills
Kaltag
KALTAG FAULT
Norton Sound
0 20 40 80 120 160 Kilometers
0 12.5 25 50 75 100 Miles

Paleozoic Sediments

Paleozoic marine sediments extend from the Delong Mountains and western Baird Mountains, westward to the Chukchi Sea. The extent of near-surface exposures of Paleozoic rocks in the area follows the trend of an east-west thrust fault located north of Kivalina, which also delineates the northern front of the Brooks Range. Many of these sedimentary units are correlative to metamorphosed basement rocks on the Seward Peninsula and Southern Brooks Range, but are relatively un-metamorphosed. The lithologies represent a stratified sequence of Devonian-age continent-derived clastic rocks, Carboniferous shale and shelf carbonates, and Upper Paleozoic (to earliest Mesozoic) mainly deep marine chert, argillite, and calcareous rocks (Plafker and Berg 1994). This section includes the Endicott and Sadlerochit Groups of the Mississippian, to the early Cretaceous Ellesmerian Sequence. The Heald Thrust Fault east of Point Hope juxtaposes Paleozoic marine sediments on the west against Mesozoic strata to the east.

Mesozoic Marine and Volcaniclastic Sedimentary Rocks

Mesozoic sedimentary strata are prominent in three portions of the KSP Planning Area: the Arctic Foothills, the Coastal Plain along the Kobuk River, and the Nulato Hills to Selawik Hills area. Cretaceous volcanic graywacke, mudstone, and sandstone dominate the westerns slope of the Nulato Hills. Lower Cretaceous marine sediments in the western Arctic Foothills and Kobuk Valley include graywacke, sandstone, shale, siltstone, and conglomerate of the Tiglukpuk (Kobuk Valley), Okpikruak, Fortress Mountain, Torok, and Kukpowruk Formations. During the Late Cretaceous and Early Tertiary, progradation of the Corwin Delta sediments from the ancestral Brooks Range formed thick coals stacked in shoreline sequences along the Coastal Plain. This sequence, referred to as the Nanushuk Group, is underlain by, and interfingers with, marine deposits of the Torok Formation, and is overlain by marine deposits of the Seabee Formation (Tyler et. al 2000).

Formations in the Arctic Foothills and Coastal Plain belong to the upper Ellesmerian and lower Brookian Sequences, and are likely conformable with older Paleozoic marine sediments in the Arctic Foothills.

Jurassic to Early Cretaceous Volcanic Rocks

An extensive belt of andesite flows and volcaniclastic rocks of the Koyukuk Terrane spans the eastern portion of the KSP Planning Area from Kotzebue Sound on the west, eastward across the KSP Planning Area and south of the Kobuk River. These rocks were likely deposited in a marine back-arc setting from Jurassic to Early Cretaceous time. Jurassic ophiolites comprise a portion of the basement lithologies, as described above.

Cretaceous Continental Rocks

The most recent consolidated lithologies consist mainly of continent-derived clastic rocks reflecting multiple marine transgression events. On the Arctic Coastal Plain, lower Cretaceous deposits up to 2,400 feet thick consist of Nanushuk Group (Brookian Sequence) continental rocks, mainly conglomerate, with shale, coaly shale, sandstone, coal, and minor tuffaceous or marine interbeds (Moore et. al 1994). In the Kobuk Valley, 16,000 to 26,000 feet of fluvial pebble conglomerates, shallow-marine conglomerates, and flyschoid sediments related to the continental margin were deposited in mid- to late-Cretaceous (Patton et. al 1994).

Cretaceous Intrusive Rocks
The Seward Peninsula and western Koyukuk Terrane record two distinct Cretaceous magmatic suites; large granitic plutons and small stock-like bodies of tin-granites (Till and Dumoulin 1994). The granitic plutons are responsible for high-grade metamorphism on the eastern Seward Peninsula. These early Cretaceous intrusives range from monzonite to syenite and form part of a belt of alkaline, low silica rock complexes and dike swarms spanning Western Alaska and the Russian Far East (Till and Dumoulin 1994). More limited low silica rock exposures occur chiefly in the eastern Seward Peninsula and Selawik Hills of the western Koyukuk Terrane (Patton et. al 1994).
The tin-granites intrude rocks of both the Seward and York Terranes. These biotite granite and minor mafic igneous rocks are related to numerous tin deposits on the Seward Peninsula.

A second Cretaceous magmatic suite, tin-granites as small stock-like bodies, intrudes rocks of both the Seward and York Terranes. These biotite granite and minor mafic igneous rocks are related to numerous tin deposits on the Seward Peninsula.

Cenozoic (to late Cretaceous) Mafic Volcanic Rocks
Tertiary to Quaternary flood basalts form large plateaus on the Seward Peninsula and in the Selawik Hills. A large field south of Kotzebue Sound in the Selawik Hills consists of vesicular olivine basalt and is likely correlative with the Imuruk Volcanics located to the west on the Seward Peninsula (Patton et. al 1994).

The Yukon-Koyukuk Province, best described as a volcanogenic province, was subjected to repeated volcanism and plutonism during Cretaceous and Tertiary times (U.S. DOI-BLM Selawik NWR Oil and Gas Assessment 1987). Tertiary-aged materials are broken into two separate timeframes. Basalt units, composed of +/- felsic volcanic rock were formed between 43 and 44 Ma, while felsic volcanic rock units +/- basalt were formed 50-65 Ma. Middle to Late Cretaceous aged material is composed of three separate stratigraphic units, with the topmost layer being made up of nonmarine marginal trough deposits, consisting of quartz conglomerate sandstone, shale and coal. The underlying stratigraphic unit is composed of fluvial-deltaic greywacke, mudstone, shale, conglomerate, tuff and coal deposits.

Cenozoic Alluvial Deposits
Alluvial, glacial, lake, dune, and beach deposits, with local coal and volcaniclastic beds are prevalent in the Kobuk River Delta, and in coastal areas. Basin-fill sedimentation in basins tens of miles wide exist locally on the Seward Peninsula, and may contain very deep accumulations (Till and Dumoulin 1994). Glacial drift and morainal material deposited during numerous Cenozoic glacial advances exist in the southwest portion of the Seward Peninsula, the southern Brooks Ranges, and on the western slopes of the Delong and Baird Mountains. On the Seward Peninsula, ice-raft deposited erratics occur on the margins of these deposits.

Permafrost
Within the planning area the Arctic Foothills is underlain by thick permafrost in areas of either fine grained or coarse grained deposits. The Central and Eastern Brooks Range, DeLong Mountains, and Baird Mountains are underlain by continuous permafrost. Discontinuous permafrost is found on the Seward Peninsula, the York, Kigluaik, and Bendeleben. The remainder of the Seward Peninsula, Kobuk- Selawik Lowland, Nulato Hills, and Koyukuk Flats are underlain by moderately thick to thin permafrost in areas of fine grained deposits and by discontinuous or isolated masses of permafrost in areas of coarse grained deposits. The Purcell Mountains north of the Koyukuk Flats is underlain by discontinuous permafrost (Krause 1985).

C. Historical and Structural Geology

Geologic investigations over the past 30 years indicate Alaska is made up of approximately fifty major crustal fragments referred to as terranes (Jones et. al 1983). The area contains individual rock terranes that have been accreted to the North American continent through plate tectonic movements. The word “terrane” refers to an assemblage of related rocks that occupy a certain geographic area, are separated from other groups of rocks by faults, and have a history of formation that is different from neighboring terranes.

The KSP Planning Area is divided into five separate exotic terranes and post-Jurassic [144 million years ago (Ma) to present] continental rocks. The divisions are based on a model developed by Goldfarb (1997) who produced a terrane map of the state. Figure 2 presented a geologic map for the KSP Planning Area which includes an inset map based on Goldfarb (1997) lithotectonic terranes. Nokleberg et. al (2000) and Plafker and Berg (1994) present similar syntheses of Alaska’s geology. The following presents a geologic framework for the KSP Planning Area.

The oldest rocks exposed in the KSP Planning Area occur along the southern flank of the Brooks Range in the south of the Arctic Alaska Lithotectonic Terrane, and on the York and the Seward Lithotectonic Terranes. Proterozoic to Middle Paleozoic (600-325 Ma) metamorphosed limestone and shale units exposed on these terranes represent continental shelf and marine slope sediments originally deposited along the passive margin of North America. These three terranes were possibly deposited as a single belt on the margin of the paleo-continent.

Middle Jurassic (163-178 Ma) tectonism generated subduction outboard of the North American continent’s stable margin. The Koyukuk-Yukon Lithotectonic Terrane, representing an island arc-type assemblage formed on the overriding plate, consists of Late Jurassic to Early Cretaceous (157-135 Ma) andesitic volcanic and volcaniclastic rocks. As subduction continued, basalt, gabbro, and oceanic sediments - an oceanic assemblage labeled the early Mesozoic (245-144 Ma) Angayucham Lithotectonic Terrane - were thrust onto the Koyukuk-Yukon Terrane. A collisional event in the mid-Cretaceous eventually closed the intervening sea between the Arctic Alaska and Koyukuk-Yukon Terranes, pinning the Angayucham Terrane greenstones as the highest structural unit in the Brooks Range. Additional Jurassic- to Mississippian-age ophiolites of the Angayucham Terrane are mapped as thrust nappes in the western Delong Mountains (Asik Mountain) and western Baird Mountains (Iyikrok Mountain). However, some ophiolites in the Western Brooks Range may have formed independently of the Angayucham Terrane rocks, and not as klippen on a synformal stack of thrust sheets as previously interpreted (Karl 1992).

As this final suturing of northern Alaska's terranes was being completed, the composite Arctic Alaska/York/Seward/Angayucham/Koyukuk-Yukon Terrane was rifted away from North America. This Middle Jurassic rifting event marks the onset of the Brooks Range Orogeny and signals the opening the Canada Basin, or modern Arctic Ocean (Moore 1994). Rifting continued through the mid-Cretaceous, eventually rotating the composite terrane 30 to 50 degrees away from the North American Craton to its present location through some combination of counter clockwise rotation, rifting and lateral translation (faulting) (Plafker and Berg 1994). The early stages of the Brooks Range Orogeny involved the final suturing of the Arctic Alaska Terrane to the composite Koyukuk-Yukon/Angayucham Terrane, an event likely responsible for the widespread blueschist facies metamorphism of Paleozoic marine sediments now exposed on the Seward Peninsula and in the southern Brooks Range. As the orogeny continued, a north-vergent fold and thrust belt developed throughout the western Brooks Range. In the Arctic Alaska Terrane, thrusting related to the end of the orogen gradually migrated northward from the Kobuk–Malamute Fault Zone to the Arctic Foothills, culminating in Tertiary thrusting and a modern compressional regime (Moore et. al 1994). The approximate northern extent of Brooks Range Orogen-related regional folding and thrusting is an east-west fault trace exposed just north of Kivalina in the KSP Planning Area, described as the northern front of the Brooks Range.

By latest Cretaceous (65 Ma), the Kobuk–Malamute Fault Zone (Kobuk Fault) had formed in response to the accretion of additional interior-Alaska terranes to the south of the Koyukuk-Yukon Terrane (Plafker and Berg 1994). North- to northwest-directed plate movements in the south created translational stresses that resulted in greater than 50 miles of generally right-lateral movement on the Kobuk Fault (Plafker and Berg 1994). Although the Kobuk Fault is still active along a limited portion, most of the transpressive forces eventually migrated south to the Kaltag-Tintina Fault outside of the KSP Planning Area. The still-active Kaltag-Tintina Fault is a deep crustal break where the Brooks Range Orogeny likely ended its rotation of northern Alaska's lithotectonic terranes.

At the same time as the latest Cretaceous movement began on the Kobuk Fault, strike-slip faulting on the western end of the composite Arctic Alaska/Seward/York Terrane began to displace the Seward and York Terranes southward and, by mid-Tertiary (44 Ma), had translated the Seward Peninsula to its current position adjacent to the Koyukuk Yukon Terrane. The exact relationship between the Seward and the Koyukuk-Yukon Terrane to the east is complicated by vertical faults and obscured by Cretaceous and Tertiary cover (Till and Dumoulin 1994).

The Seward Peninsula is divided into its two lithotectonic terranes, the York and Seward, based on differing structural relationships, metamorphic history, and magmatism. Situated in the central and eastern portion of the Seward Peninsula, the Seward Terrane is dominated by Precambrian (?) to early Paleozoic schists and marble, and intruded by three suites of Cretaceous granitic rocks (Till and Dumoulin 1994). Alternatively, the York Terrane occupies the western Seward Peninsula; it is composed of early- to middle-Paleozoic (and possibly older) limestone, argillaceous limestone, dolostone, and phyllite. The York Terrane is cut by Late Cretaceous tin-bearing granites, but lacks evidence for the two additional intrusive suites apparent on the Seward Terrane. The boundary between the Seward and York Terranes is poorly exposed but thought to be a major thrust fault because of its sinuous map trace, a discontinuity in metamorphic grade, and differences in stratigraphy across the thrust zone (Till and Dumoulin 1994).

Magmatism possibly related to the final digestion of subducted material beneath the Koyukuk-Yukon Terrane continued into the late Cretaceous, as evidenced by volcanism and intrusive events recorded on the eastern Seward Peninsula and across the Koyukuk-Yukon Terrane.

The Kuzitrin Basin and the Koyuk Trench originated in the Cenozoic, possibly late Miocene or early Pliocene, during an early phase of widespread orogenic movements that also brought the Bering and Chukchi Seas into existence (Hopkins 1963).

D. Geophysics and Geochemistry

Coal Geochemistry

Merritt and Hawley (1986) summarize the geochemistry of coalfields and coal districts of Alaska; workers have produced a significant volume of literature detailing the State of Alaska’s undeveloped coal resources in the north of Alaska. The quality of coal is ranked by the amount of metamorphism it has undergone since burial. Coal qualities are divided into four classes or ranks: in decreasing order of carbon content and heat value, these are anthracite, bituminous coal, subbituminous coal, and lignite. Within the bituminous class, coals are further subdivided into five groups based on the amount of volatile matter (low, medium, and high volatile present) and heat value (A, B, and C) (DOE 2004).

The Northern Alaska Coal Province likely represents the largest coal-bearing province in the United States (Merritt and Hawley 1986). The Planning Area intersects the western edge of this coal province and includes significant bituminous coals in the northern portion of the Arctic Foothills (north of the 69^{th} parallel at Cape Lisburne) and subbituminous resources on the North Slope (near Point Lay). Additional bituminous resources occur in the Kobuk Basin and lignite coal resources have been identified on the Seward Peninsula. Table 4 presents a comparison of the resource potential and quality of coal in the Planning Area.

Table 4 – Coal Resources, Northern Alaska Kobuk Seward Peninsula Planning Area.

Province (Fields in KSP)*	All Identified Resources (*in millions of short tons*)	Hypothetical Resources (*in millions of short tons)*	Coal Rank
Northern Alaska (Kukpowruk, Lisburne, Cape Beaufort Fields)	~150,000 (Kukpowruk, Lisburne, Cape Beaufort Fields)	~4,000,000 (entire Northern AK Coal Province)	High-volatile bituminous, subbituminous, and lignite with minor anthracite
Kobuk (East and West Kobuk Fields)	---	10	Subbituminous and Lignite
Seward Peninsula (all fields)	5 (Chicago Creek Field)	110	Lignite and Subbituminous
Totals	**155,000**	**4,110,010**	

*Note: All listed coal fields are located within KSP Planning Area except a portion of the East Kobuk Field.

Geothermal Data

The central portion of the Seward Peninsula has long been recognized for its geothermal potential. A reconnaissance survey of geothermal potential completed for the area included helium-in-soil survey data, geophysical methods (gravity, deep seismic refraction, very-low frequency (VLF) and resistivity methods), and remote sensing (radar and infrared airborne) techniques (Wescot and Tuner 1981). Although essentially regional in scope, the study also focused on delineating the geothermal occurrence in the Pilgrim Hot Springs area.

Workers returned in 1982, completing a geothermal drill program in the Pilgrim Hot Springs area (Economides 1982). This study constituted a drilling and reservoir engineering analysis for geothermal gradients and sources.

III. DESCRIPTION OF LEASABLE MINERAL RESOURCES

A. Coal

Sedimentary rocks with known coal deposits occur in several areas within the planning area. These resources are concentrated primarily in the northwest portion of the State and described as the Northern Alaska Coal Province, which includes three fields; Cape Beaufort, Kukpowruk, and Lisburne Fields (Figure 3). The Northern Alaska Coal Province is contained within the Colville Basin. Other coal resources within planning area include occurrences in the Kobuk Basin (East and West Kobuk Fields), the Chicago Creek Field, and other identified coal districts on the Seward Peninsula (Figure 4). Each field is discussed in terms of origin and occurrence, historical information, and development potential.

Alaska offers numerous advantages for energy development:
• Alaska is centrally located to serve the entire Pacific Rim. It is closer to the Far East markets than Australia, Canada, or South Africa.
• Alaska is well positioned to serve the Canadian and U.S. west coasts.
• Alaska is positioned to serve European markets by the Northern Sea Route. Specialty armored freighters are able to routinely transit the polar passage during the summer.
• Alaska offers a stable political environment and a well-trained work force.
• Alaska has government participation through tax credits and the provision of infrastructure.

Cape Beaufort Field

The Cape Beaufort Field is located on the northern coast of Alaska. Its physical boundaries extend offshore west of Cape Lisburne then east-northeast to the Kukpowruk River south of Point Lay (Figure 3). Of the three northern fields within the Colville Basin, Cape Beaufort has the greatest development potential. The field is classified as having a high Leasable Mineral Potential (LMP), specifically within the area known as the Deadfall Syncline. The Deadfall Syncline is located east of Cape Beaufort with the main exploration area located near the confluence of the Kukpowruk River and Deadfall Creek, about 25 miles northeast of Cape Beaufort.

Within the field, BLM managed lands consist of several partial townships of native selected lands, and several townships of state selected lands. There are no BLM unencumbered lands within the Cape Beaufort Field.

Origin and Occurrence

The major coal-bearing units in the Colville Basin occur in two sedimentary rock sequences; the Nanushuk Group (Early to Late Cretaceous), and the Colville Group (Late Cretaceous). This section will concentrate on the non-marine rocks of the Nanushuk Group as it has been identified as having the majority of the coal resources.

The local geology is dominated by east-west trending anticlines and synclines. The synclines contain bituminous coal beds associated with the Nanushuk Group, specifically the Corwin Formation (AGS Staff 1990). The Corwin Formation is the primary coal bearing formation associated with the Nanushuk Group and is comprised of shales, sandstones, and conglomerates deposited in delta and alluvial plain environments. The Nanushuk Group may underlie 30,000 square miles of northern Alaska, where coal resource estimates range from 400 billion to 4 trillion short tons. At Corwin Bluff, the Nanushuk Group is more than 11,000 feet thick, of that, approximately 4,000 feet is the Corwin Formation. The Nanushuk Group gradually decreases to the northeast before disappearing altogether in eastern NPRA (Callahan and Martin 1981). Between 150-200 coal beds have been correlated in the Corwin Formation of western Alaska to the Chandler Formation further east in NPRA (Merritt 1988). The other Cretaceous-age formations; Fortress Mountain, Torok, and Kukpowruk are marine and largely barren of coal. Coals in the Colville Group are thinner, less abundant and of inferior quality (Sable and Stricker 1987) and are primarily limited to the Prince Creek Formation (Merritt 1986).

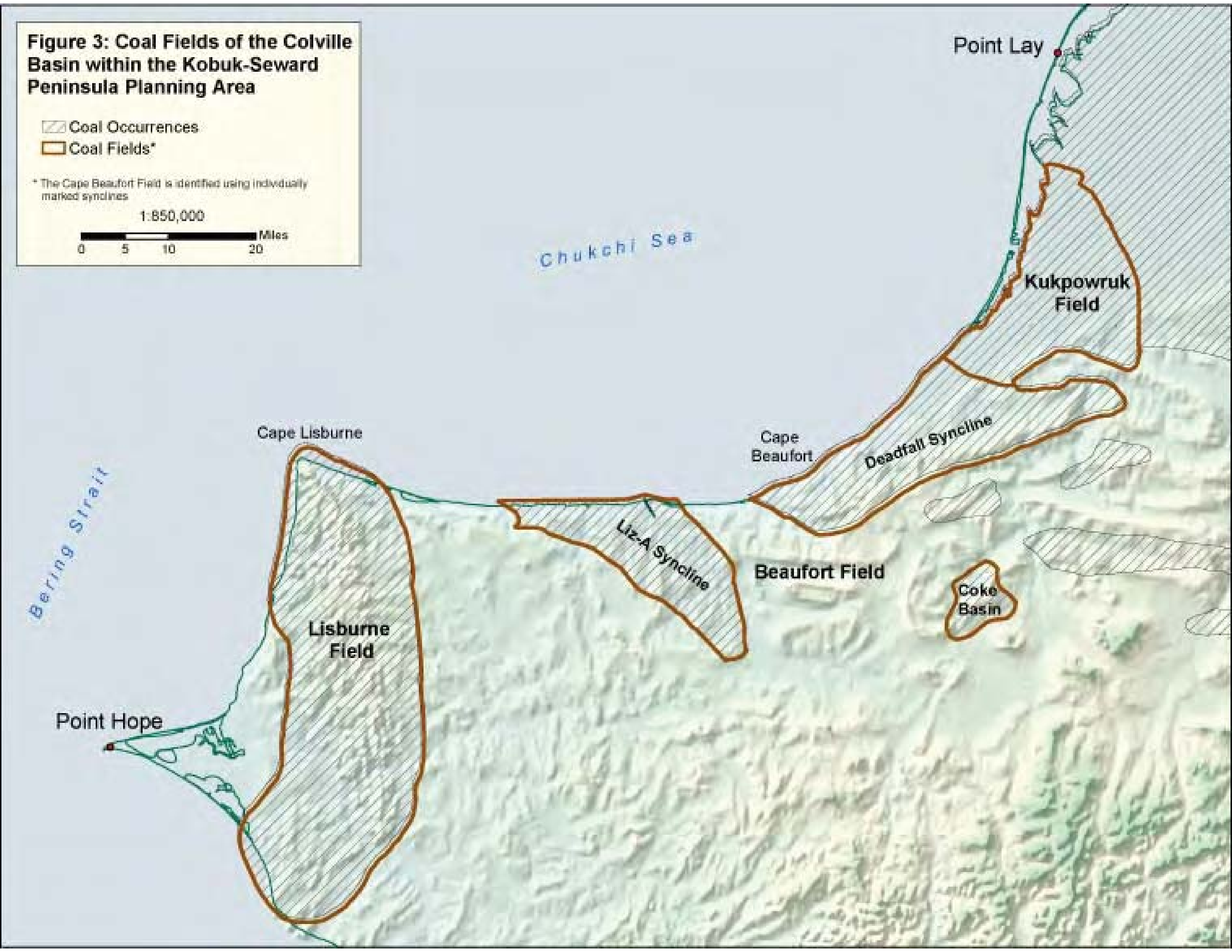

Figure 3: Coal Fields of the Colville Basin within the Kobuk-Seward Peninsula Planning Area

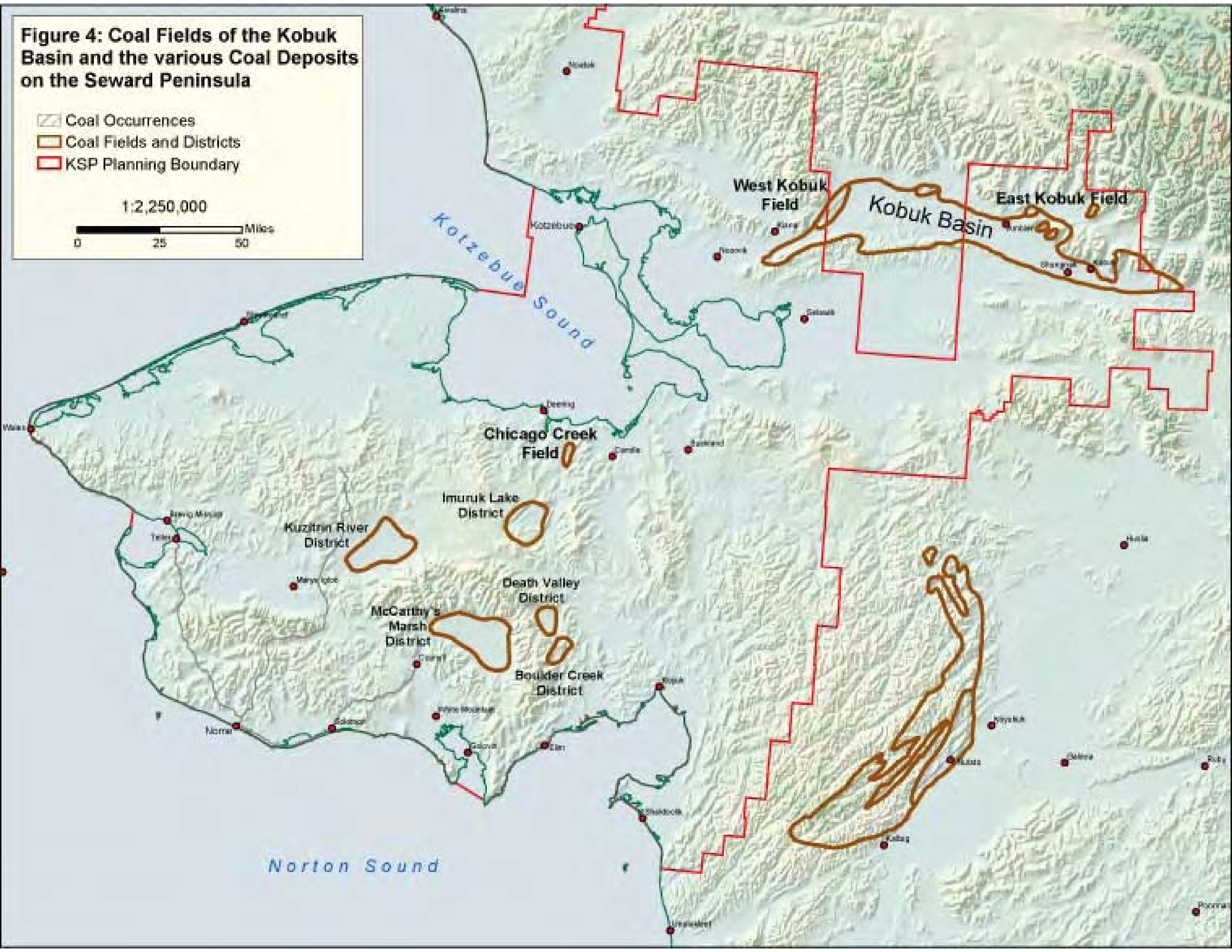
Figure 4: Coal Fields of the Kobuk Basin and the various Coal Deposits on the Seward Peninsula
Coal Occurrences
Coal Fields and Districts
KSP Planning Boundary
1:2,250,000
0
25
50
Miles
Kotzebue Sound
Norton Sound
West Kobuk Field
Kobuk Basin
East Kobuk Field
Chicago Creek Field
Imuruk Lake District
Kuzitrin River District
Death Valley District
McCarthy's Marsh District
Boulder Creek District

Deformation of the Corwin Formation increases to the south where there are tight folds, steep dips and numerous faults. Northward toward the coast the formation contains open folds, flat dips, and few faults (Barnes 1967). Drill hole data from Clough et. al (1995) indicate that the coals are laterally continuous and can be reliably estimated.

In the Cape Beaufort Field, the Corwin Formation has 146 coal beds that have been identified**,** 28 of which are potentially minable (Clough et. al 1995). According to the Special Report 37 published by the Alaska Department of Natural Resources (ADNR), the Corwin Bluff of the Corwin Formation, Nanushuk Group is located within the Lisburne Field, however, the composition and age is more consistent with the Beaufort Field. Further discussion with personnel from the ADNR confirmed the Corwin Bluff to be consistent with the Cape Beaufort Field. The Corwin Bluff is located 35 miles west of Cape Beaufort and 2.5 miles east of Cape Lisburne. At the bluff 80+ coal beds over 1-ft thick are exposed; 17 of the beds range between 2.5 and 9.0 feet in thickness with the beds generally dipping from 30° to 45°. Analysis of the coal yielded the following average values: moisture 3-6%, volatile matter 28-41%, fixed carbon 47-58%, ash 4-12%, and a free-swelling index of 1.5 (Merritt 1988). The Corwin Formation outcrops all along the Beaufort Sea coastline.

Further east, toward the Deadfall Syncline, coal deposits are almost exclusively confined to the Corwin Formation (Clough et. al 1995). The coal beds are bituminous in rank with thicknesses varying from 14 inches to 13 feet. Nine beds are considered minable with a thickness of greater than 42 inches. The coal ranges from horizontal to gently dipping up to 20°. Sampling indicated the following results: a free-swelling index of zero at the surface with swelling properties increasing with depth, moisture content measured 2.5-8% (mean 4.6%), volatile matter ranged from 22-36% (mean 33.9%), fixed carbon 35-56% (mean 53.9%), ash 5.5-22% (mean 7.6%), sulfur 0.20%, and a heating value of 10,900-13,200 Btu/lb (average 12,900 Btu/lb). Coking potential increases with depth. Coal from 200 feet shows the most prominent coking characteristics (Merritt 1988).

Coal seam K3 of is one of the thickest seams in the Deadfall Syncline area. It is high volatile A bituminous rank and has a maximum thickness of 17 feet, with an average ash content of 9 percent and over 10 feet of this seam averages less than 4 percent ash (AGS Staff 1990). In this same area, there is evidence of burned coal within the Kukpowruk Formation (Barnes 1967).

Additional coal occurs within a structural depression along the Kukpowruk River, known as Coke basin. In this area, 10,000 feet of the Corwin Formation is exposed with six coal beds ranging from 1-3 feet and exhibit good coking qualities. The as-received moisture value is 0.8 percent with a heating value of 15,300 Btu/lb. The coal appears to have been upgraded by tectonic deformation or a nearby igneous intrusion (Clough et. al 1995).

In addition to the Deadfall Syncline reserve estimates, the remaining portions of the Cape Beaufort Field including the Liz-A Syncline area has had approximately 390 million short tons identified with 1.7 billion short tons hypothetical (Figure 5) (Merritt, 1988).

Figure 5: Resource potential for the Deadfall Syncline, the remaining Cape Beaufort Field, and the Kukpowruk River Field in terms of identified and hypothetical short tons.

Area	Identified	Hypothetical
Deadfall Syncline	500	5,000
Cape Beaufort/Liz-A Syncline	390	1,700
Kukpowruk River	275	1,200

The Liz-A Syncline is another area where potentially minable coal occurs within the Cape Beaufort Field. The Liz-A Syncline is located along the coast west of Cape Beaufort. There are 26 known coal beds greater than one foot in thickness, however, most are relatively thin or limited in extent. The thickest coal seam exceeds 15 feet, while three others are greater than eight feet (Dames and Moore 1980). Structurally, the Liz-A Syncline is less desirable with dips measured at the southwest end of 40 degrees or more. The coal beds numbered 10 through 20 have an average (as received) 8,000 to 9600 BTU value, based on surface samples. The two thickest coal beds, 16.5 ft. and 11.5 ft., have gentle dips, ranging between 15° to 20° with an average Btu of 12,970 and an ash content of 7.3 percent. Although the beds cannot be traced laterally for more then 5 miles in either direction, an economical product could be produced if related to the Deadfall Syncline mining project.

Historical Information

Coal in Arctic northwest Alaska was first officially reported by A.J. Collier, a member of the Beechey expedition to the Arctic Ocean in 1826-27 (Collier 1906, 1908). In 1879, whaling ships and U.S. Revenue cutters utilized the exposed coal beds in the coastal sea cliffs at Corwin Bluff, 2.5 miles east of Cape Lisburne, to replenish the fuel supply of whaling ships. In 1884-85, Henry D. Woolfe and J. W. Kelly employees of the Pacific Steam-Whaling Company built a house and wintered at Corwin Bluff**,** but their attempts to operate coal mines were met with little success (Collier 1906). Several years later in 1888-89, bituminous coal from the Thetis Mine near Corwin Bluff was supplied (in unknown quantity) to the U.S. Revenue cutter *Thetis* (Merritt 1986). The discovery of gold at Nome in 1898 drew attention to these deposits as a possible source for fuel to supply mines on the Seward Peninsula; and several companies were organized to exploit them. Large areas of coal land were staked and several cargos of coal, probably over 1,000 short tons in all, were mined and sold at Nome in 1900 and 1901 (Collier 1906). Historic coal prospecting and mining occurred at Cape Beaufort, Cape Sabine, Thetis Mine, and Corwin Bluff (Clough et. al 1995).

The Cape Beaufort/Deadfall Syncline region underwent a significant amount of exploration in the 1950s and 1960s, which led to some minor local production. The more significant events include the Morgan Coal Company exploring the coking potential on the Kukpowruk River near the Deadfall Syncline. In 1954, they drove a 70 foot tunnel into a coal seam exceeding 20 feet in thickness. From 1961-1963, Union Carbide was active in investigating the coking coal along the Kukpowruk River (Merritt 1986). From 1970-77, Kaiser Engineers performed detailed mining and economic evaluations on coal deposits in the Kukpowruk River area as well as the Deadfall Syncline area. From 1980 to 1985, the Department of Geological and Geophysical Survey (DGGS) Northwest Alaska Coal Project examined lignite to bituminous coal in the area to evaluate the practicality of coal as an alternative energy source for Point Lay. This area was a localized effort to the Northwest Alaska Coal Project which evaluated coal for 28 regional villages. The 13 most promising sites were investigated by geologists from DGGS and BLM. In 1983, the Deadfall Syncline area was explored to determine the thickness, extent, and quality of selected coal beds in the area. This was accomplished by drilling 27 test holes to depths of 238 feet in the western portion of the Deadfall Syncline. Results showed a minimum of 20 million short tons of strippable coal at a 5:1 ratio. The coal was superior (high volatile A or B bituminous, ash 8-20%, moisture 2-8%, sulfur less than 0.1%, with occasional coking) to other areas tested in the Cape Beaufort Field. The Liz-A Syncline locality was drilled the following year, identifying a resource of 22 million short tons and a potential resource of 25 million short tons (Merritt 1985).

Activity continued in 1984 as the Arctic Slope Consulting Engineers drilled 47 test holes in the Deadfall Syncline area (Arctic Slope Consulting Engineers 1984). They also tested open-pit and underground mining methods for the coal. A result of the studies identified the resource as a 500-million ton field of high-rank coal (Alaska Department of Commerce and Economic Development 1988).

Current Production

Currently, coal is not being developed in the Cape Beaufort Field. However, ASRC has entered into a five year agreement with BHP Billiton to conduct exploration and possibly development of coal resources within the Cape Beaufort Field (Adams 2006). BHP Billiton has committed to ASRC’s environmental studies and the establishment of a community consultation process. If exploration results are favorable, BHP Billiton will begin project concept studies to determine preliminary feasibility and possible mine development (Hurst 2006).

The Northern Alaska Coal Province west of NPR-A may contain up to 1.0 trillion short tons of coal (Merritt 1988). The best potential is the Deadfall Syncline deposit where some mining has previously occurred. The Arctic Slope Regional Corporation has test-mined both surface and underground (Alaska Department of Commerce and Economic Development 1988). Exploration permits were approved in 1992 with 1,000 short tons mined by the ASRC (Energy Information Administration 1994).

The development potential of the Deadfall Syncline is considered moderate to high. Between 2001 and 2002, the Department of Transportation and Public Facilities (DOT&PF) examined potential energy and mineral deposits statewide to determine if investing in transportation systems would accelerate resource development. This project is known as the Resource Transportation Analysis (RTA), which is part of the Industrial Roads Program (IRP). During Phase I of the RTA, it examined access to resources and the prospect of transport to world markets. Findings determined that for mining operations (including coal), long-distance overland routes do not work well based on today’s marine transport-based systems. The Deadfall Syncline coal deposit meets the requirements of the DOT&PF to move this project to Phase II (McKinnon 2004). As of December 2004, reconnaissance engineering by CH2M Hill through ASRC, NANA, and TechCominco is underway to determine if there is a practical road route between the Deadfall Syncline deposit and the Delong Mountain Terminal currently serving Red Dog (Liles, 2005). At this point, the 90-mile road connection appears to be more practical than building a new port along the coast. Rails do not appear feasible due to steep grades and terrain breaks. With a road in place, a mine could eventually export 1-2 million short tons of high-quality coal per year to Asia for use in coal-blend formulas. Reconnaissance engineering is scheduled to be completed by May 2005 (McKinnon 2004).

If the road route was deemed unfeasible, construction of a nearby port facility and shorter haul road could be considered. The construction of 5.4 miles of haul road from the mine site to a port facility at Omalik Lagoon would require approximately 170,630 cubic yards of fill. The road would be designed for 35 ton off highway trucks for speeds up to 40 mph, with a 5% maximum grade. The width of the road would be 24 feet, with a minimum of 4 foot embankment, underlain with a geotextile fabric, with horizontal curves of 10 degrees or less. Turnouts would be placed at 2000 foot intervals. The roadway would not cross any major drainage (Western Arctic Coal Development Program 1986). A 2,800 foot lead-in channel that is 130 feet wide would need to be dredged to a depth of 13 feet to accommodate barges (AGS Staff 1990).

There are a few coal permits in the area. The State of Alaska has one coal permit located near the Deadfall Syncline. It is located approximately 40 miles southeast of Point Lay near the Kuchiak River (Bruce Busby, Personal Communication 2005). The permit has an extensive reclamation component and lands disturbed by exploration activities are in an environmentally stable condition (State of Alaska 2005). The BLM has two preferential right coal leases in this area. The leases were issued in 1999 and would need to show diligent development (as identified in CFR 3483.1) in order for non-competitive lease renewal in 2009. The leases are currently owned by the estate of Morgan Coal Company. If the leases were to expire, the land would be conveyed to ASRC.

Lisburne Field

Origin and Occurrence

Coal in the Cape Lisburne area occur primarily in the Mississippian-age Kapaloak Formation, and outcrop intermittently from Niak Creek (5 miles south of Cape Lisburne) to Cape Thompson, a distance of 45 miles. The formation consists of nonmarine sandstone, mudstone, shale and coal, with minor occurrences of conglomerate and marine limestone (Clough et. al 1995). On average coal bed thickness does not typically exceed 4 feet and many beds are crushed and broken (Dames & Moore 1980). Coal seams are more abundant in the sea cliffs at Cape Dyer than at Cape Thompson where coal bed exposures rarely exceed one foot (Conwell and Triplehorn 1976). The coal beds associated with Kapaloak Formation are typically known for single outcrops compared to the Corwin Formation coal beds which are generally lenticular.

Thickness and distance of coal beds vary based on the underlying geology. The geology is structurally complex due to folding and faulting which makes it difficult to determine resource estimates. For this reason, the DGGS decided not to test drill the area. Outcrop samples at Cape Dyer and the Kukpuk River were collected. Results for the low-volatile, coal showed heating values of 11,457 to 14,731 Btu/lb with low sulfur content 0.63%, a moisture content of 5.7%, and 12% ash (Clough et. al 1995). Similar values were also found in samples obtained by Conwell and Triplehorn in June 1975. Results indicate a high-quality coal of semi-anthracite ranking (Conwell and Triplehorn 1976).

Historical Information

Coal exploration in the Cape Lisburne area was first officially reported by A.J. Collier, a member of Captain Beechey's expedition to the Arctic Ocean in 1826-27 (Collier, 1906, 1908). The nearby Corwin Bluff was mined in 1879 to replenish the fuel supply of whaling ships. Ten years later coal from the Thetis Mine near Corwin Bluff was supplied (in unknown quantity) to the U.S. Revenue cutter *Thetis* (Merritt 1986). It is likely both sites were visited by previous whaling parties. In 1900-01, over 1,000 short tons of coal was mined and shipped for use in Nome (Clough et. al 1995). While most of the activity occurred in the younger Cretaceous coals on the north coast, the coal deposits south of Cape Lisburne were known. Collier inspected the coal deposits from Cape Dyer to Cape Thompson and recognized its complexity (Collier 1906).

Current Production

Despite these large deposits, there is no potential for development unless nearby infrastructure were to be developed. Even if development and production were to occur in the Deadfall Syncline area, it is unlikely this would increase the development potential for the Lisburne Field. The harsh arctic climate should also be taken into consideration as exporting coal could only occur during the ice-free months (June-September).

Kukpowruk Field

Origin and Occurrence

The Kukpowruk Field is located northeast of the Deadfall Syncline toward the western boundary of the National Petroleum Reserve in Alaska (NPRA). See Figure 3. It lies at the western edge of the Howard Syncline (Merritt 1988). The composition and quality are similar to the Beaufort Field.

Approximately 40 bituminous coal beds ranging from 1 ½ feet to 13 feet are exposed along a 25 mile stretch of the Kukpowruk River (commencing at the mouth). Of these coal beds, 17 are thicker than 42 inches. The beds lie in eastward trending folds that dip between 12-55 degrees (Barnes 1967). The most promising area lies 28 miles south-southeast of Point Lay, and 14 miles directly east of the Chukchi Sea coast where a 22-foot coal bed outcrops above the river. Above this thick seam are 12 other beds varying from 1 to 9 feet in thickness. The 22 foot seam dips at 15 degrees while other exposed outcrops in the field dip from zero degrees to near vertical (Merritt 1988). Coal occurrences are found in both the Corwin Formation and the upper part of the Kukpowruk Formation.

The coals sampled in the area are low-ash, low-sulfur and high-volatile A or B. Other qualities of the sampled coal include a free-swelling index of 4.5, moisture content at 0.8 to 10% (mean of 2.8%), volatile matter was measured at 35.2%, fixed carbon was 58.5%, ash 3.5%, sulfur 0.25%, and a heating value ranging from 11,900-14,100 Btu/lb and an average of 13,860 Btu/lb. Strippable reserve estimates indicate approximately 20 million short tons. Total estimated resources are approximately 3 billion short tons. (Merritt 1988).

Historical Information

The Kukpowruk River was referenced by AJ Collier in his 1906 report, but is unclear whether they explored the river or examined the outcropping coal seams. The Morgan Coal Company and Union Carbide did some exploration in 1954 and 1961, respectively. The Morgan Coal Company still maintains an active federal preferential right coal lease south of the Kukpowruk Field.

From 1980 to 1985, the DGGS Northwest Alaska Coal Project examined the bituminous coal occurrences in the area in order to evaluate the practicality of coal as an alternative energy source for Point Lay (Clough et. al 1995).

Current Production

There is no current production. While the coal is of high value (low ash, low sulfur, low moisture, high fixed carbon, high Btu/lb), it is unlikely the resource will be developed unless there were infrastructure to support it. Judging from past history, the development potential of the Kukpowruk Field by itself is not enough to justify building infrastructure and mining the coal. If a transportation route were to link the Deadfall Syncline to a port facility, then development of the Kukpowruk Field is a possibility.

Chicago Creek Field

Origin and Occurrence

The Chicago Creek Field, also known as the Kugruk River Field is located on the Seward Peninsula and occupies an area of less than 40 square miles (Merritt 1986). The terrain consists of gentle sloping hills with tundra and a topographic relief of about 400 feet. The area is completely underlain by permafrost. The coal field lies in a north-south trending linear trough that may be as much as 2 miles wide. North-south faults bound horst and graben structures. The horsts are made up of Precambrian York Slate (or its equivalent), which is the source of the gold placer deposits. The grabens contain the coal bearing formations (Manning and Stevens 1983). The seams strike north-south and dip from 45 to 70 degrees. The coal occurs in one primary bed that is roughly 100 feet thick with intermittent partings of sand and clay (Clough et. al 1995). Coal was sampled by the Denali Drilling, Inc. under contract with the State of Alaska in which 14 holes were drilled to a maximum depth of 100 meters (Decker et. al 1987). On an as-received basis, the coal averaged 35.58% moisture, 26.28% volatile matter, 30.86% fixed carbon, 7.28% ash, a heating value of 6987 Btu/lb with 0.97% sulfur. These numbers are based on an as-received basis. The coal has been dated back to the Late Tertiary with a lignite rank (Manning and Stevens 1986).

Drilling has identified coal for a distance of at least 8,000 feet both north and south of the mine portal. The bed likely continues further to the north. The coal-bearing unit dips steeply to the west. This could signify its proximity to the eastern fault on the margin of the graben. Drill core indicated that that the dip of the coal bed decreases with depth which may indicate drag-folding near a fault (Manning and Stevens 1983).

Identified resources are 4.7 million short tons within 300 feet of the surface (Retherford et. al 1986) and hypothetical resources are 10 million short tons. Considering the low rank of the coal, probable future development would be by surface mining (Merritt 1986). Approximately 1.5 million short tons can be mined at a stripping ratio of 1.7:1. Another 3.2 million short tons could be mined at stripping ratios of 4:1 or 5:1 (Retherford et. al 1986).

Historical Information
The first discovery of coal on Chicago Creek (Figure 6) came in 1902 as a result of gold prospecting. The coal is located about one mile upstream from the confluence of Chicago Creek and the Kugruk River (Moffit 1906). In 1903, the same prospectors drove a 200 foot incline into the coal seam and began mining the coal (Reed 1933). Coal mining claims were staked in 1905. Coal mining reached peak production from 1907 until 1911, at which time approximately 110,000 short tons of coal were mined for placer operations in the area. An adit was dug into the bank of the creek where the coal mine was operated during the winter months to prevent thawing around the adit during the summer (Clough et. al 1995). The underground mine was worked at four different depths (33, 80, 100, and 144 feet) below the shaft house (Manning and Stevens 1983). After 1920, some coal from the slack pile was used for domestic use. In the winter of 1923, the incline was re-timbered in an unsuccessful attempt to re-open the mine. Presently, the incline is filled with water (Reed 1933).

Figure 6: Chicago Creek Mine photo courtesy of the Alaska State Library.

In addition to the Chicago Creek mine, two other coal mines were active in the Chicago Creek Field during the 1910s and 1920s. The Kugruk Coalmine is located 6 miles south on the Kugruk River between Montana and Reindeer Creeks. An incline was tunneled into a shale bluff 12 feet above the river. The incline slopes downward 156 feet to a depth of 20 feet before sloping an additional 144 feet to a depth of 35 feet. The strike is N 15° E, with an average dip of 62° W. The coal does not crack as badly as what is found in Chicago Creek. The other mine, the Superior Coalmine is across the river and 500 feet south of the Kugruk Coalmine. The incline was 165 feet long at an angle of 29 feet from vertical, which made the lowest drift 75 feet below the surface. The coal seam is about 52 feet wide, although it is debatable as to whether the hanging wall was reached. Strike and dip are similar to the Kugruk mine. The incline has since been filled with gravel due to different flooding events from the river (Reed 1933).

Hawley Resource Group, under contract to the State of Alaska Division of Geological and Geophysical Surveys, continues a geological mapping, drilling, and geophysical exploration program at Chicago Creek, Seward Peninsula.

In 1982, Denali Drilling Inc., under contract to the State of Alaska, conducted a drilling program and geologic investigation of the Chicago Creek coal deposit which is located about 70 miles south of Kotzebue (Manning and Stevens 1983). The program lasted through 1985 and included field mapping, core and auger drilling, and both down-hole and surface geophysics. Over 60 holes were drilled to a maximum depth of 300 feet, from which hundreds of samples were analyzed (Goff et. al 1986).

Current Production

The coal seam at Chicago Creek has not been adequately explored to speculate on the reserves to develop a mining plan. Additional exploration drilling is necessary to properly evaluate the feasibility of developing the coal at Chicago Creek to provide power for the Kotzebue area. The biggest obstacle in terms of development would be the steep dip of the coal seams. With the steep dip, open pit mining would soon result in a high stripping ratio which would severely limit the economic potential (Manning and Stevens 1983).

Mine development would require construction of a haul road, coal-stockpile pad, airstrip, camp facility, and diversion ditch. Construction equipment, camp facilities, and fuel would be delivered to Willow Bay and hauled inland during the winter. Gravel for the roads and airstrips could be taken from the nearby Kugruk River (Retherford et. al 1986).

The coal field is located primarily on either Native lands or Native Selected lands. The entrance to the mine is on Native land.

Kobuk Basin (West and East Kobuk Fields)

Origin and Occurrence

The Kobuk Basin is comprised of the East and West Kobuk Fields and several other coal occurrences. Most exposures concentrate along the outcrops of the various drainages within the basin. The westernmost exposure is on the north side of the Kobuk River near its confluence with the Kallarichuk River. Coal exposures also occur along the Singauruk River, Hunt River, lower Ambler River, lower Kogoluktuk River, and in the Lockwood Hills (Barnes, 1967). Reconnaissance surveys done in the mid 1980s located three main outcrops. One is on the Kallarichuk River where minor production occurred on two coal beds each roughly 2 foot in thickness. The other two sites are along the Kobuk River. One location has several coal beds 2-3 feet thick dipping about 30 degrees, and the other consists of an 18 foot thick dipping at 25 degrees (Merritt 1988).

The coals are mid to late Cretaceous from the now obsolete Bergman Group. The structure shows generally shallow dips (less than 30') defining broad open folds, locally steeply dipping near high-angle faults (Merritt 1988). The coal seams tend to be less than 3 feet thick. The coal is bituminous in rank, characteristically high volatile C bituminous.

The heating values range from 9200-10,500 Btu/lb, with sulfur content varying between 0.4-1.1%, and ash ranging from 7-35% (Merritt 1985).

A portion of this deposit lies within Fish and Wildlife Refuge lands in the Hockley Hills and along the Singauruk River. This area was studied in 1982 by the DGGS to fulfill a request by NANA Regional Corp to determine the nature of the coal deposit (Clough et. al 1982).

Historical Information
In 1908, a mine was opened by Captain Theielen on the Kobuk River about a mile below the Kallarichuk River. Approximately 150 short tons of coal was mined primarily to accommodate placer miners with some of it shipped to Kotzebue where it sold for $17 a ton (Cathcart 1920). Literature did not indicate the quantity at which the coal was extracted. In 1929, the same mine site was reopened by Alexander Haralan to use in his placer gold operation (Merritt 1988).

Current Production
Future mining and development potential is very low due to the lack of infrastructure and portions of the Kobuk Basin are located within both the confines of the Kobuk Valley National Park and the Selawik Wildlife Refuge.

McCarthy Marsh District

Origin and Occurrence
McCarthy’s Marsh is a topographic depression that contains between 3,000 and 10,000 feet of Tertiary-age sediment fill. The basin is fault bounded to the north and east by the Bendeleben and Darby Mountains, and to the southwest by a less definable upland. Coal float with a wood-like, lignitic appearance was found on Omilak, Windy, and Telephone Creeks (Clough et. al 1995). The Tertiary strata exposed on Omilak Creek (then called the Rathlatulik River), was described as woody and lignitic in appearance, with pieces up to 24 inches-thick in the creek bed. The southern portion of the basin, primarily within the Solomon Quadrangle, has the most coal potential. Float similar to Omilak Creek was found in the bed of Dry Canyon Creek (Goff et. al 1986).

Historical Information
Early exploration for coal was conducted in 1909 by geologists from the USGS. They focused primarily on Omilak Creek. A composite map of gravity data acquired over many years shows McCarthy's Marsh to be the largest Bouger gravity anomaly on the Seward Peninsula, with strongly negative gravity readings suggesting a sedimentary fill between 3,000 and 10,000 feet deep (Barnes 1977). This indirect evidence would indicate that there is potential for a large volume of coal-bearing rocks underlying McCarthy’s Marsh. It has been suggested that the coal at depth would be of higher quality and perhaps thicker seams than what has been found at the surface (Goff et. al 1986).

Current Production
Given the depth of the sedimentary basin, it is possible that considerable coal underlies this area. However, outcrops are sparse so the amount of coal present is difficult to

determine. Without existing infrastructure and the sensitive nature regarding the Marsh, the development potential would be low.

Kuzitrin River District

Origin and Occurrence

The Kuzitrin River District is located northwest of McCarthy's Marsh along the upper Kuzitrin River drainage. The 250 square mile Kuzitrin basin contains Tertiary-age coal-bearing rocks of the Noxapaga Formation that include claystone, sandstone, conglomerate and coal (Dames and Moore 1980). Outcrops are found along Turner Creek and in a pingo west of the Noxapaga River. A sample collected near Turner Creek indicated a ranking of lignite with an as-received heating value of 6,653 Btu/lb, 33.56% moisture, an ash content of 3.46%, and sulfur 0.16%. Aside from the very low ash and sulfur content, it is very similar to the other Tertiary coals found on the Seward Peninsula (Goff et. al 1986).

Historical Information

During the early 1900s lignite was mined from a 1 to 12-ft-thick bed in a pingo located near Turner Creek, west of the Noxapaga River. Coal was used in thaw boulders and in household fuel, but was noted to have high ash content and poor heating value (Hopkins 1963). In 1982, the BLM and DGGS geologists excavated this bed and collected a sample for analysis (Goff et. al 1986).

Current Production

Future coal resources for the Kuzitrin River District area are difficult to determine due to the small sample size of two poorly exposed and slumped outcrops. The lateral continuity of coal beds is uncertain. Assuming the coal were continuous, extraction would be difficult due to the overlying tundra and swamp. Development could present major alterations to the drainage system (Clough et. al 1995). Coal use as fuel was discontinued sometime around 1950 as diesel fuel was brought in by tractor (Hopkins 1963).

Imuruk Lake District

This district is identified in the Alaska Division of Geological and Geophysical Surveys Special Report (SR) 37 by Merritt and Hawley in 1986. However, little information exists about specific geology or occurrence. According to the map, coal occurrences within the district are primarily Tertiary lignite. No other data was found.

Death Valley District

Origin and Occurrence

Located east of the Darby Mountains, quartz monozonite plutonic rocks occur with Tertiary volcanic and sedimentary rocks. Coal occurs in outcrops along the eastern portion of the Death Valley Basin and as float along the Tubutulik River. The coal and related sedimentary rocks were deposited in the area of ancestral Lake Tubutulik, created when early Eocene basaltic lava dammed the ancestral Tubutulik River and flooded the valley (Dickinson 1988). Coal grade is probably lignite, given the fact the coal was formed under the same event as the Boulder Creek District (which is lignite rank).

Historical Information
There has been no documented coal exploration in this district.

Current Production
This district has never been drilled, but it is likely filled with similar coal-bearing Tertiary sedimentary rocks that are present in the Boulder Creek District (Merritt 1986). Specifics about the coal characteristics is generally unknown. Development potential is low despite a high development potential for Uranium in the area which could create nearby infrastructure. It is unlikely the mine with an expected operation window of approximately 10 years would use low-ranking lignite coal over diesel. The expense involved in mining the coal, creating and operating a coal fired plant, and shutting it down 10 years later would be too cost prohibitive. It is unlikely the coal would become a stand alone mine even if infrastructure were present. The low rank of the lignite would hold little interest to industry unless seams of considerable size (such as Chicago Creek) were discovered.

Boulder Creek District

Origin and Occurrence
It is located east of the Darby Mountains within the Death Valley Basin. This district is south of the Death Valley District and differs in that Eocene to Holocene basalt flows has covered much of the sedimentary rocks. The sediments and volcanic rocks were deposited in a graben formed in the north-south Kugruk fault zone (Dickinson et. al 1987). It is presumed this basin developed in conjunction to the tectonic origin of the Chicago Creek deposit. A coal outcrop approximately 35 feet in thickness at Grouse Creek is slumped and highly weathered (Clough et. al 1995). This bed could be part of another bed discovered during drilling by Houston Industrial Minerals Corporation in 1980. Drill hole DV-30 discovered a 175-foot lignite lens and is overlain by Eocene basalt, coal, lacustrine mudstone, sandstone and a Quaternary basalt flow (Dickenson et. al 1987). Depth to the thickest coal bed is roughly 300 feet with other encounters with coal as shallow as 70 feet below the surface. The coal and related sedimentary rocks were deposited in the area of ancestral Lake Tubutulik, created when early Eocene basaltic lava dammed the ancestral Tubutulik River and flooded the valley (Dickinson 1988).

The coal occurs in Paleocene nonmarine sandstone along with uranium (with an average grade of 0.27%). The coal sampled from the drill hole averaged an as-received ash content of 3.3%, total sulfur content of 0.52%, and a heating value of 7,680 Btu/lb. Samples collected from the outcrop on Grouse Creek yielded an average as-received heating value of 6444 Btu/lb (Clough et. al 1995).

Historical Information
There has been no documented coal exploration in this district.

Current Production

The reserve estimates on the weathered Grouse Creek outcrop are difficult to determine primarily due to the slumping overburden. The 175 foot coal bed would indicate considerable coal resources in the Boulder Creek District within the Death Valley Basin. However, the depths at which this coal lies (about 300 feet) and the distance to tidewater (over 25 miles) make development potential unfavorable.

B. Coalbed Natural Gas

Coalbed natural gas is low cost, clean burning, natural gas recovered and produced from coal beds. Unlike conventional gas, it is a nontraditional reservoir in the sense that the coalbeds are both the source and reservoir for the methane gas (Tyler et. al 2000). The conversion of plant material to coal (coalification) produces large amounts of gas, comprised of mostly methane, that is then stored on the internal surfaces of the coal. Because coal has such a large internal surface area, due to fractures or cleats, it can store 6 to 7 times the amount of gas than a conventional gas reservoir of equivalent rock volume. Gas within the coal is held in place by hydrostatic pressure (Nuccio 1997).

Exploration costs for CBNG are low, and wells used to extract CBNG are cost effective to drill. Because methane is less dense than oxygen, it rises to the surface as water pressure is reduced within the coal seam by pumping. Coalbed natural gas is extracted, compressed, and then put into pipelines and burned like any other natural gas accumulation. No specialized technology is needed for its immediate utilization. Gas content generally increases with coal rank, with depth of burial of the coalbed, and with reservoir pressure (Nuccio 1997).

In the early stages of coalbed natural gas production large amounts of water may be produced. Water disposal from the production of coalbed natural gas has been handled in many different ways depending on the water quality, quantity and location that production is occurring. In some locations water has been disposed of at the surface when it has been relatively fresh. However, most water is injected into a rock at depth often below that of the coalbeds being produced where the water quality of the host rock is less than that of the injected water.

The ideal scenario for maximum coal bed methane production would be to have the following:

- Thick, laterally continuous coals of high thermal maturity
- Adequate permeability
- Basinward flow of groundwater through coals of high rank and gas content orthogonally toward no-flow boundaries (aka fault systems, structural hingelines, facies changes)
- Generation of secondary biogenic gases
- Conventional trapping along those boundaries to provide additional gas beyond that generated during coalification.

Application of these criteria would indicate that the Colville Basin has the highest potential for coalbed resource development of all rural Alaska coal basins. With coalbed natural gas being a relatively new concept, exploration to remote locations has not been conducted. Aside from the Colville and Kobuk Basins, coalbed natural gas data does not exist for the other described fields or districts.

Colville Basin

Origin and Occurrence

The resource beneath the Colville Basin is only partially realized. The basin, predefined in the coal section (Figure 3), has coalbed natural gas potential primarily within the Nanushuk Group, which extends nearly continuously from the Corwin Bluff to the Sagavanirktok River near Deadhorse (Merritt 1986). Conventional trapping, both stratigraphic and structural, are presumed to be the mechanism in place. The Colville Basin is generally characterized by folding and faulting along east-northeast and east trending axis generally parallel to the Brooks Range (Tyler et. al 2000).

The DGGS has chosen to focus on the western portion of the basin near Wainwright, Atqusuk (both outside of the planning area), and Point Lay because of better coal exposures. Approximately 150 coal beds ranging from 5-28, with a few over 40 feet, have been documented. The majority of these beds display dominant face cleating. Spacing of the primary cleat in outcrops range between 0.25-0.75 inches. The surface fractures are an indication that the subsurface coal may have similar characteristics. The fractures would allow water and gas to flow into the wellbore. The coal rank of high-volatile A bituminous coals at depth ranges from 300-6,000 feet (Tyler et. al 2000). These depths are suitable for exploration, in a relatively relaxed tectonic stress regime. Permeability could be enhanced by the underlying gently folded strata of the Meade and Wainwright Arches. Producibility of the coal could be enhanced by the coal laying within or near the permafrost zone, which tends to increase gas concentrations (Smith 1995). Well logs studied for the wellsites within the NPRA tend to show strong mud-log gas kicks below the permafrost zone and no mud-log gas kicks within the permafrost zone (Tailleur and Bowsher 1979).

The coal is found primarily in the Lower Cretaceous within the Kukpowruk, Corwin, and Chandler Formations of the Nanushuk Group (see Figure 7). Total coal thickness typically exceeds 300 feet (Tyler et. al 2000).

Coals associated with the Lisburne Field are Mississippian in age and primarily occur within the Kapaloak Formation. They outcrop along the Lisburne Peninsula over a 45-mile north-south trending belt. Approximately 13 coal beds have been identified that outcrop along 2,200 feet that is extensively faulted and folded. Because of this complex structure, depth, and distance to villages, these coals are not considered targets for coalbed natural gas development in the near future (Smith 1995).

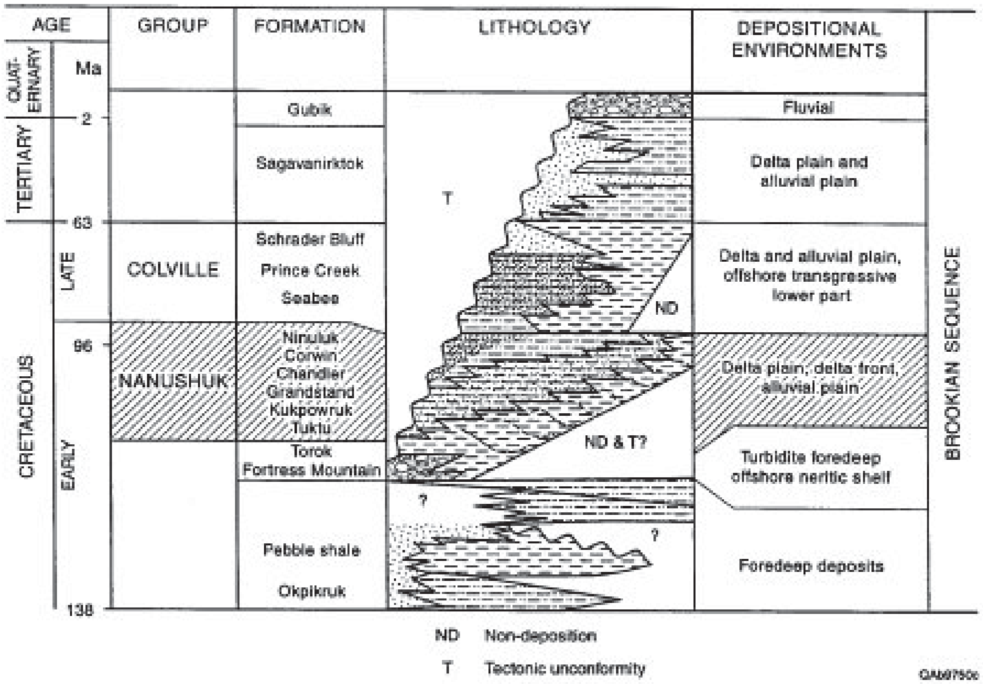

Figure 7: Typical lithology associated with the Brookian Sequence. The Nanushuk Group is identified by the hatch pattern. From Tyler et. al, 2000.

Historical Information

Subsurface data is available from drill holes in the western portion of NPRA that penetrated the Kukpowruk and Corwin Formations. Findings indicated that abundant coal seams up to 20 feet thick were consistently encountered. These coal seams have been documented in outcrops along the Kukpowruk River and in other easterly wells within NPRA (Tyler et. al 2000).

The Tunalik wellsite (west of Wainwright) penetrated over 3,600 feet of coal-bearing section with coal beds estimated over 300 feet. The 1980 Husky Oil NPR Operations for U.S. Geological Survey report for Tunalik described several gas shows within the Nanushuk Group (5,000-6,000 foot depth) that were probably associated with coalbed natural gas. Further investigation by Tailleur and Bowsher in 1979 confirmed that the upper kilometer of the Tunalik Test Well reflected coal gas locked in clathrates to depths exceeding 350 meters. Coal encountered downhole below 500m showed no sign of methane, which would indicate methane-hydrate stability above that level.

Kaolak Test Well No.1 drilled through 4,500 feet of the Nanushuk Group with 255 feet of coal (Sable and Stricker 1987). Two 10 foot beds and 2 thinner ones are within 1,000 feet of the surface and 32 beds ranging from 4 to 26 feet in thickness were recorded between 1,000 and 3,000 feet (Barnes 1967). Between 1,183-1,203 feet lies a 17 foot coal bed with black, shiny coal with blocky fracture. Coalbed natural gas was discovered while drilling this section according to the drilling report published by the United States Geological Survey (USGS) (Collins and Bergquist 1958).

Meade Test Well No. 1 also had gas shows associated with coal beds. Collins, while discussing the formation test between 0-3,038 feet (the coal bearing section of the Nanushuk Group), stated that the "critical flow prover measured 124,500 cubic feet of gas per day, at 74 psi, 74 degrees: and 301,000 cubic feet per day at 39 psi, 54 degrees F." Collins went on to state that faint shows of oil and conventional gas was poor, however gas was discovered in conjunction with the coal beds. While drilling, at least 21 coal beds were discovered measuring between 4 and 30 feet thick. The Meade Test Well is outside the boundary of the planning area, however the geology and associated strata are similar to what could be found in the Kobuk-Seward RMP.

Current Production

There is no current coalbed natural gas production within the Colville Basin. The extent of the resource potential is unknown, due largely to the lack of data. In 2006, the DGGS and BLM have plans to bring a small drill rig to the village of Wainwright (just outside of the planning area) to test the methane potential for supplying the village with gas. If successful, the same rig could be moved west to Point Lay (within the planning area) for drilling.

Kobuk Basin

Origin and Occurrence

Coalbed natural gas potential in the Kobuk fields has not been estimated. Few reports and limited information leave much to speculate when it comes to the full extent of the coal resource. Published information indicates smaller coal seams are in the majority. Additionally, surface vitrinite-reflectance value of the Cretaceous coal-bearing rocks to both the north and south of the Kobuk Basin are very high (1.3-5%), suggesting coals may have already passed through the hydrocarbon-generating window. The ideal thermal maturity has a vitrinite-reflectance value of 0.8-1.0%. There is still potential for gas as it is largely unknown if the coals are permeable and have developed cleats. The Cretaceous sedimentary rocks in the area are characterized by low permeability. Further potential exists if the coal beds are laterally continuous, which could give rise to biogenic gas generation and accumulation. However, the amount of accumulation would depend on the localized coal bed geometry and the presence of permeability barriers for trapping the coal gases (Tyler et. al 2000).

Historical Information

There is no history of previous exploration for coalbed natural gas in the Kobuk Basin.

Current Production

There is very low potential for coalbed natural gas exploration or development in the Kobuk Basin. The rating of very low potential is based on several factors; it has a very high thermal maturity, the known coal beds are thin, and the lack of adequate surface and subsurface data (Tyler et. al 2000).

C. Oil and Gas

The USGS conducts estimates of oil and gas resources in the United States based on the concept of a “play,” which is defined as a set of oil and/or gas accumulations sharing similar geographic boundaries and geologic attributes, such as source rock, reservoir type, and trap (USGS 1995; Beeman et. al 1996). There are three known basins in the planning area; Colville Basin, Kotzebue Basin, and Selawik Basin. Eight plays were identified within the Colville Basin, four in the Kotzebue, and none in the Selawik. By definition, plays identified by the USGS are to be considered high potential for future oil and gas exploration.

Five hydrocarbon wells have been drilled within the boundaries of the planning area. Figure 8 shows these locations.

Pending Oil and Gas Leases

There are 19 suspended oil and gas lease offers within the planning area. Most of these pending noncompetitive offers were filed prior to 1975 and grandfathered in by Congress when it passed Sec. 5106(a) of the 1987 Federal Onshore Oil and Gas Leasing Reform Act (101 Stat. 1330-256, 259) (Reform Act). The Reform Act requires BLM to issue leases for these suspended offers unless such lease issuance would not be lawful under other applicable law.

The 19 suspended oil and gas lease offers comprise 34,935 acres of BLM unencumbered and Native selected lands within the Kobuk-Seward Peninsula planning area (BLM unencumbered = 2 leases, 2,945 acres; Selected lands = 17 leases, 31,990 acres). If the Native selected mineral estates underlying these offers are not conveyed as entitlement lands to a Regional Native Corporation under the Alaska Native Claims Settlement Act, the offers will be adjudicated and, if appropriate, leases will be issued at such time as the land withdrawals suspending the offers are removed.

If the mineral estates are conveyed, the offers will be rejected. As is the case with all leases issued under the Mineral Leasing Act of 1920, as amended, site-specific environmental analyses will be performed and appropriate bonding will be required prior to the authorization of any on-the-ground lease activities.

Colville Basin

Origin and Occurrence

The Colville Basin is one of two basins in Alaska where hydrocarbons are currently being produced. Hydrocarbon generation in the Colville Basin commonly correlates with deposition of the Cretaceous-Tertiary Brookian sequence. It was driven eastward by progradation of the Brookian shelf margin along the basin axis. Accordingly, a hydrocarbon generation “front” was initiated in the southwest of the NPRA (within the KSP Planning Area) during the Albian, migrated across the NPRA during the Albian and Cenomanian, and progressed through the state lands from the Cenomanian to the Eocene (Burns et. al 2003).

Within the planning area, four confirmed plays and four hypothetical plays have been identified in the Colville Basin. The confirmed plays are Topset, Turbidite, Ellesmerian-Beaufortian Clastics, and the Fold Belt. The hypothetical plays include; Lisburne, Lisburne Unconformity, Endicott, and Western Thrust Belt (Magoon et. al 1996). These plays are broken down into a more specific level in of detail in NPRA where extensive studies have taken place. For the purposes of this report, the two eight plays described by the USGS in their 1995 assessment will be used.

Topset Play excerpted from Magoon et. al 1996.
This conventional oil and gas play consists of stratigraphic and structural (fault) traps in sedimentary reservoirs of Cretaceous and Tertiary age. It includes those rocks represented on seismic records in the topset position of a clinoform sequence. The rocks consist of marine and nonmarine deltaic sandstone, siltstone, shale, conglomerate, and coal assigned to the Lower, Middle and Upper Brookian sequences encompassing the Nanushuk Group and Sagavanirktok Formations and the uppermost parts of the Torok and Canning Formations. These are the youngest petroleum-prospective rocks in the province. The play is limited to the area of relatively flat-lying strata north of the fold and thrust belt that generally corresponds to the Coastal Plain Physiographic Province. The play covers an area of about 26,400 sq mi.

Potential reservoir rocks consist of sandstone and conglomerate. Stacked shoreline sandstones may be present in areas where basin subsidence equaled sedimentation for prolonged periods of time. Fair to good reservoir continuity is expected parallel to depositional strike (northwesterly). Porosity is approximately 10 to 20 percent in the western part of the play.

Within the play interval, deltaic shales and mudstones are thermally immature and probably gas-prone. Directly beneath the play interval, marine foreset and bottomset shales (Torok and Canning Formations) are poor to fair oil source rocks that are immature to marginally mature in the play area. Deeper in the section, rich oil source rocks of the Hue Shale, an underlying informally designated pebble-shale unit, the Kingak Shale, and the Shublik Formation are mature beneath most of the play area. Multiple oil sources for the play are indicated by the presence of both the high-sulfur Barrow-Prudhoe-type oil and the low-sulfur Simpson-Umiat-type oil. Source rocks reached maturity in the Late Cretaceous in the western part of the play. Maturity occurred as a result of burial by rocks of this play. Migration pathways have been noted along faults and along clinoform bedding.

Assumed traps are mostly stratigraphic and are related to facies changes or by cut and fill features; structural traps are formed by small-displacement normal faults. The faults and interbedded shales are expected to provide only fair to poor seals, therefore hydrocarbon accumulations will probably consist of oil rather than gas. A total of 250 exploratory wells have penetrated this play, however, all are located east of the planning area. Oil accumulations have been discovered at Fish Creek, Cape Simpson, Milne Point, and West Sak. The potential for undiscovered oil and gas resources greater than the minimum size used in this assessment is considered good. Potential increases from west to east.

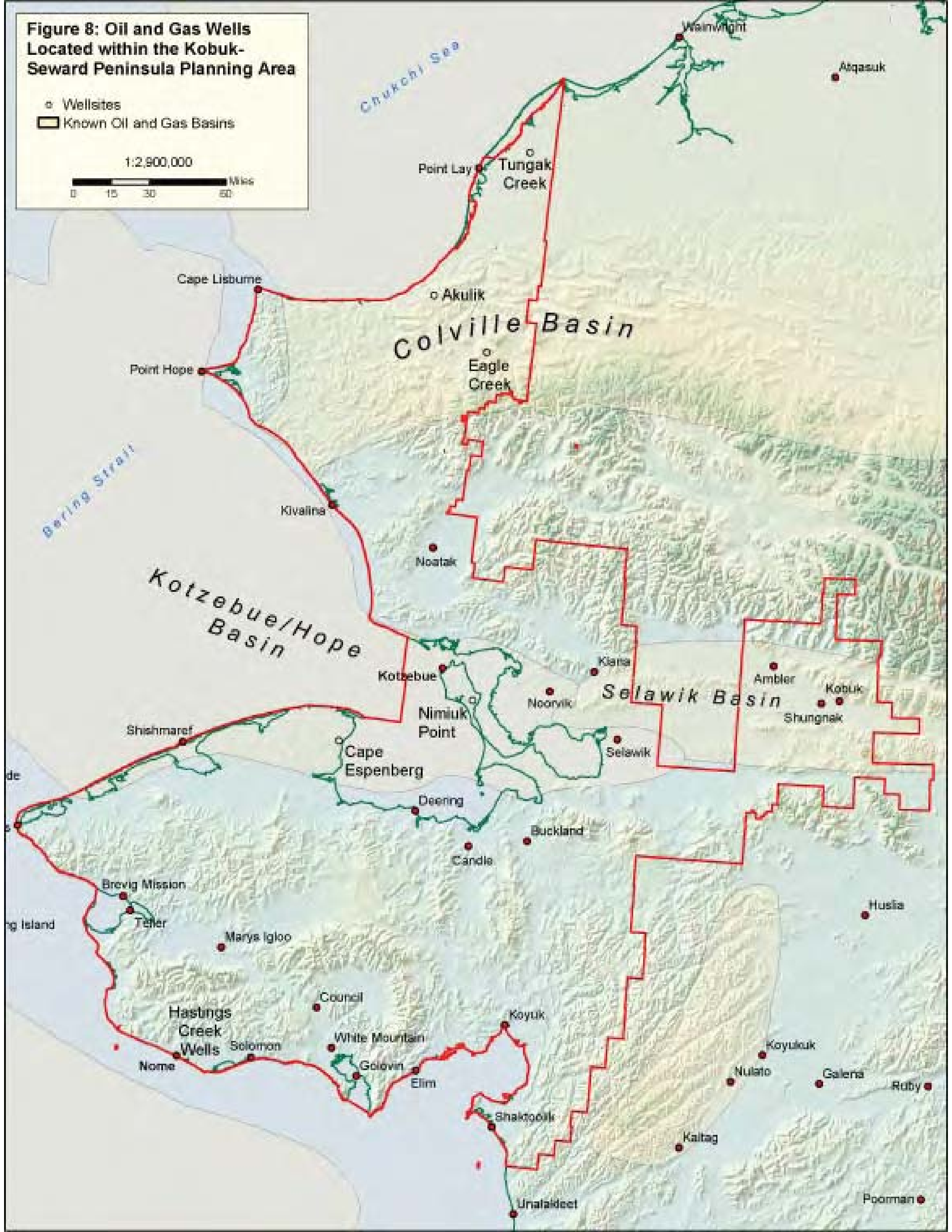
Figure 8: Oil and Gas Wells Located within the Kobuk-Seward Peninsula Planning Area
Wellsites
Known Oil and Gas Basins
1:2,900,000
Miles
0
15
30
60
Chukchi Sea
Bering Strait
Wainwright
Atqasuk
Point Lay
Tungak Creek
Cape Lisburne
Akulik
Colville Basin
Point Hope
Eagle Creek
Kivalina
Noatak
Kotzebue/Hope Basin
Kotzebue
Kiana
Noorvik
Selawik Basin
Ambler
Kobuk
Shungnak
Nimiuk Point
Shishmaref
Cape Espenberg
Selawik
Deering
Buckland
Candle
Brevig Mission
Teller
Marys Igloo
Huslia
Council
Hastings Creek Wells
Koyuk
Solomon
White Mountain
Nome
Golovin
Elim
Koyukuk
Nulato
Galena
Ruby
Shaktoolik
Kaltag
Unalakleet
Poorman

Turbidite Play excerpted from Magoon et. al 1996.
This play consists of stratigraphically trapped deep-marine sandstone reservoirs of Cretaceous and Tertiary age and includes those rocks represented by the foreset and bottomset seismic reflectors in the clinoform sequence north of the fold and thrust belt. The play includes Lower, Middle, and Upper Brookian turbidites assigned to the Torok and Canning Formations. Rock types in this play are predominantly marine shale and siltstone with minor amounts of sandstone. Total area of the play is 30,500 sq mi.

Reservoir rocks may occur anywhere within the play interval, but they are most frequently encountered in the lower half of the play interval as toe-of-slope or basin-plain turbidites. Individual sandstone bodies are expected to be thin and laterally discontinuous; aggregate reservoir thickness may occasionally reach 100 ft or more. Reservoir porosity is expected to vary from 5 to 30 percent, with porosity higher to the east.

Source rocks include the marine shale of the Torok and Canning Formations, which are expected to be relatively gas-prone. The Hue Shale is the richest oil-prone source rock known in the play interval and lies directly beneath the turbidites. Other oil-prone source rocks beneath this play include the pebble shale unit, the Kingak Shale, and the Shublik Formation. Throughout most of the play, the top of the thermal zone of oil generation lies within or just below the lower part of the play interval.

The turbidite reservoir sandstones in this play are the deep-water equivalents of the deltaic deposits of the overlying Topset play. Thus thermal maturation of the source rocks was the result of burial by rocks of this and the overlying play. The timing relative to stratigraphic-trap formation is judged to be ideal, and migration distances relatively short because some turbidites rest directly on the Hue Shale.

Assumed traps are stratigraphic and are related to facies changes, or they are traps formed against small-displacement normal faults. Faults and the surrounding thick marine shales are expected to provide fair to good seals.

More than 200 exploratory wells and 2,000 development wells have penetrated this play; but relatively few have been targeted for deposits within the play. Four oil accumulations have been discovered (Flaxman Island, Badami, Stump Island pool of Point McIntyre field, and Colville Delta). Sizes of these accumulations have not been reported. Oil has been recovered from turbidite reservoirs in numerous exploratory wells in the play. Prospects for additional discoveries are speculated to be excellent.

Ellesmerian-Beaufortian Clastics Play excerpted from Magoon et. al 1996.
This confirmed conventional oil and gas play consists of combined stratigraphic and structural traps of sandstone reservoirs in the gently south-dipping Permian to Early Cretaceous section, above the Lisburne Group. The play interval consists mostly of siltstone and shale with as much as 10-percent sandstone. The northern boundary of the play is the southern boundary of the Barrow Arch Ellesmerian and Barrow Arch Beaufortian plays, where the play interval may be as thin as 400 ft. The southern play

boundary lies beneath the Foothills Physiographic Province, where the play interval rocks become involved in Brooks Range compressional structures. The total area of the play is about 35,000 sq mi.

Potential reservoirs include sandstone in the Echooka and Ivishak Formations, the Sag River Sandstone, several unnamed sandstone units in the Kingak Shale, Kuparuk Formation, and stratigraphic equivalents of the Kemik Sandstone. These sandstones were deposited primarily in shallow-marine environments. Porosities may reach 25 percent in the northern parts of the play area, but are anticipated to decrease to less than 10 percent in the southern parts. Most reservoirs, particularly those with the best porosity, are expected to occur beneath the Coastal Plain Physiographic Province.

The play interval contains many of the richest source rocks on the North Slope, including the Kavik Shale, the Shublik Formation, the Kingak Shale, the pebble shale unit, and the Hue Shale. These shales range from marginally thermally mature in the northernmost parts of the play to overmature in the southern parts. At the top of the play interval, the (R_o) 0.6 percent value lies just north of and parallel to the -10,000 ft contour and the R_o 2.0 percent value approximates the -20,000 ft contour.

Basin reconstructions and burial-history calculations show that source rocks reached maturity as a result of burial by Cretaceous and Tertiary foreland basin fill. Maturity was achieved in the Late Cretaceous in the western part of the play and the early to middle Tertiary in the easternmost part. The migration direction would have been generally northward. Oil and gas accumulations are expected to be trapped in stratigraphic or a combination of fault and stratigraphic traps. Shales within the play interval are expected to provide adequate seals.

Exploration status: The Walakpa gas field was discovered in 1977 by the NPRA program. Although the size of the field is undetermined, an estimate of 60 BCF is probable and an upper size limit of 1-4 TCFG is possible if the reservoir is widely distributed (Richard Glenn, personal communication 1994). Oil and gas shows are reported in several wells in this play; good gas shows have been encountered in the South Simpson and Tunalik wells. A few dozen exploratory wells have penetrated this play, only a few of which were drilled for prospects in the play interval.

The potential for undiscovered oil and gas resources greater than the minimum size used in this assessment is considered good.

Lisburne Play excerpted from Magoon et. al 1996.
This hypothetical play consists of structurally and stratigraphically trapped carbonate or clastic reservoirs in the gently south-dipping Lisburne Group. The northern play boundary is the Lisburne onlap limit west of long 154° W. The Lisburne Play extends southward to the area beneath the northern Brooks Range at depths greater than 26,000 ft. Only autochthonous (originating where found) Lisburne rocks, are included in this play. The play-interval thickness may vary from zero at the onlap edge to as much as 4,000 ft in areas such as the Ikpikpuk-Umiat Basin. Total area of the play is about 57,000 sq mi.

Potential reservoir rocks include dolomite, limestone, and sandstone. Dolomite, the most important reservoir with porosity occasionally as high as 25 percent, is expected to occur most abundantly in the late Mississippian part of the Lisburne Group. Dolomite of this age is not expected in the northernmost or western part of the NPRA because Lisburne rocks of this age are missing by onlap. Limestone porosity in the Lisburne is expected to average less than 5 percent. Sandstone, which may be common along the northern onlap edge in the NPRA, may be partially to completely cemented with calcite and, thus, may serve as a marginal reservoir. Depth to the top of the Lisburne in the play ranges from 10,000 ft along the northern play boundary to greater than 26,000 ft in the south.

Potential source rocks include marine shale in the overlying Sadlerochit Group, marine shale and limestone within the Lisburne, and marine to lacustrine shale and coal in the underlying Endicott Group. Where truncated by the regional Lower Cretaceous unconformity at the easternmost part of the play, the pebble shale unit and the Hue Shale overlying the unconformity may be important source rocks. Limited geochemical data suggest that all except the pebble shale unit and Hue Shale are fair to poor, gas-prone source rocks that are thermally mature in the northern part of the play and supermature in the southern part. R_o values of 2.0 percent generally coincide with the -12,000 ft structure contour. Oil residue is often encountered in porous dolomite in the Lisburne Group, and hydrogen sulfide gas was encountered in interbedded limestone and shale near the Lisburne-Endicott Group boundary at a depth of about 17,500 ft in the Inigok-1 well. UIn western Alaska, burial-history analysis indicates that hydrocarbons may have been generated in Early Cretaceous burial by the Colville Basin fill. Because the reservoir traps formed relatively early, the postulated timing of thermal maturity and migration for this play are regarded as favorable. In general, maturation would have occurred earlier in the southern and western parts of the play and the migration direction would have been from south to north.

Stratigraphic traps related to the Lisburne Group onlap edge and facies changes are expected in the northern part of the play area. Numerous low-relief (<200 ft) structural traps, noses, and faults are seismically mapped in the NPRA, apparently the result of folding and faulting during Mississippian, Pennsylvanian, and Permian(?) time. In the northwestern part of the NPRA, numerous seismic anomalies have been mapped; these may be carbonate buildups (reefs) and may constitute yet another potential trap type. Sealing rocks are expected to be interbedded shale and impermeable limestone.
Less than a dozen exploratory wells have been drilled for prospects in this play; no hydrocarbon accumulations are known. Available data suggests limited resource potential, probably all natural gas. Because of the relatively few wells and large area covered by this play, there are many geologic uncertainties. Chiefly, distribution, continuity, and thickness of reservoirs, size and integrity of traps (adequacy of seals), and the richness of source rocks.

Lisburne Unconformity Play excerpted from Magoon et. al 1996.
The Lisburne Unconformity Play consists of stratigraphic traps developed as a result of differential erosion on the regional Permian or Lower Cretaceous unconformities that lie at the top of the Lisburne Group. The play is hypothetical because the amount of differential erosion on the unconformities is largely unknown and the coincidence of

relief with porous carbonate rocks is also unknown. The play encompasses the entire area of Lisburne Group beneath the Permian and Lower Cretaceous Unconformities, including that area overlying the Barrow Arch. The southern limit of the play coincides with the southern limit of the Lisburne Play. Total area of the play is about 60,3500 sq mi. Reservoirs: Reservoir rocks are expected to be porous dolomite and limestone, similar to that in the Lisburne Play. Depth to the Permian unconformity in the play area ranges from about 8,000 ft to greater than 26,000 ft.

Potential source rocks are mostly gas-prone marine and nonmarine shale. Oil-prone source rocks younger than the Lisburne Group may be in fault contact with Lisburne rocks along the Barrow Arch. Timing and migration are considered good because the traps would have formed early. Postulated traps are envisioned to consist of erosional scarps and remnants of porous Lisburne Group carbonates sealed by the overlying Sadlerochit Group. These traps are analogous to those that trap most Mississippian oil and gas accumulations beneath the plains of Alberta.

As many as 50 exploratory wells may have penetrated this play, but few, if any, were drilled for prospects. Because of the small probability for traps and favorable reservoir, the chance for hydrocarbon accumulations greater than the minimum size used in this assessment is considered remote.

Endicott Play excerpted from Magoon et. al 1996
This hypothetical play consists of combined structural and stratigraphic traps in sandstone reservoirs in the Mississippian Kekiktuk Conglomerate, and sandstone or dolomite reservoirs in the overlying Kayak Shale, both formations belong to the Endicott Group). The northern boundary of the play west of long 155° W. is the onlap edge of the Endicott Group; east of this longitude, it is the southern boundary of the Barrow Arch Ellesmerian Play. The Endicott Play extends southward to the area beneath the northern Brooks Range at depths greater than 24,000 feet. Only autochthonous rocks, those not involved in Brooks Range deformation, are included in this play. Thickness of the Endicott Group is generally 100-1,000 ft but locally may be as much as 10,000 ft. Total area of the play is about 57,500 sq mi.

Potential reservoir rocks consist primarily of fluvial to shallow-marine(?) quartzose sandstone and conglomerate within the Kekiktuk Conglomerate. Minor amounts of shallow-marine dolomite and sandstone are present in the overlying Kayak Shale. Porosity is expected to be less than 10 percent because of extreme burial depths; about 90-percent of the play lies at depths greater than 12,000 ft. and half of the play at depths greater than 24,000 ft.

Potential source rocks include coal and lacustrine shale in the Kekiktuk and marine shale in the Kayak. Limited geochemical data suggest that all are poor to fair, gas-prone source rocks that are thermally mature in the northern part of the play and supermature in the southern part. R_o values of 2.0 percent generally coincide with the -12,000 ft structure contour. Hydrogen sulfide gas was encountered in interbedded limestone and shale near the Lisburne-Endicott Group boundary at a depth of about 17,500 ft in the Inigok-1 well.

Burial-history analysis indicates that hydrocarbons may have been generated as early as Permian time in the Ikpikpuk-Umiat basin; elsewhere, generation did not occur until Early Cretaceous burial by Colville basin fill. Because the reservoir traps formed relatively early, the proposed timing of thermal maturity and migration for this play is regarded as favorable. In general, maturation would have occurred earlier in the southern and western parts of the play and the migration direction would have been from south to north.

Traps are expected to be structural folds and faults that were developed during the formation of Endicott Group basins in Mississippian, Pennsylvanian, and Permian(?) time. Numerous low-relief (<200 ft) structural traps, noses, and faults are seismically mapped in the NPRA at the Lisburne Group level, apparently the result of folding and faulting during Mississippian, Pennsylvanian, and Permian(?). Interbedded Kekiktuk Conglomerate shale and the overlying Kayak Shale are probable seal rocks.
Exploration status: Less than a dozen exploratory wells have been drilled for prospects in this play; no hydrocarbon accumulations are known.

Available data suggests limited resource potential, probably all natural gas. Because of the relatively few wells and large area covered by this play, there are many geologic uncertainties. Chief among these are the distribution, continuity, and thickness of eservoirs, size and integrity of traps (adequacy of seals), and the richness of source rocks.

Fold Belt Play excerpted from Magoon et. al 1996.
This confirmed conventional oil and gas play consists primarily of anticlinal traps in Cretaceous and Tertiary sandstone reservoirs in the northern part of the Brooks Range fold and thrust belt. The Fold Belt Play is situated north of the Western Thrust Belt Play and south of the Topset Play; its western border is the offshore national 3-mile territorial limit in the Chukchi Sea, and its eastern border the same offshore limit in the Beaufort Sea. The Fold Belt play encompasses the Nanushuk Group; the Torok, Sagavanirktok, and Canning Formations; the Hue Shale, the pebble shale unit, and the Kemik-equivalent sandstones. Even older strata may be included in the play along its southern border. Total area of the play is about 36,500 sq mi.

Potential reservoirs are sandstones representing deltaic, shallow-marine, and turbidite environments. Porosity is expected to range from 5 to 30 percent and to improve eastward across the play. Drilling depths range from the near-surface to greater than 20,000 feet. Potential source rocks include generally gas-prone shales of the Nanushuk Group and the Sagavanirktok, Torok and Canning Formations and the underlying more oil-prone shales of the Hue Shale, pebble shale unit, Kingak Shale, and Shublik Formation. Gas-prone source rocks within this play range from thermally immature to mature, whereas most oil-prone source rocks range from mature to overmature. The eastern part of the play is considered more oil prospective than the western part because of greater thicknesses of the oil-prone Hue Shale in the east. Oil seeps and oil-stained sandstones are numerous.

Hydrocarbon migration would initially have been controlled by depositional geometries (such as clinoforms and onlap relations). Migration directions along clinoforms would have been generally southwestward. Hydrocarbons that were trapped during this time may have re-migrated into anticlinal traps following deformation. The time lag between maturation and structural deformation is not known. Traps are faulted anticlines related to Brooks Range deformation. In addition, all of the stratigraphic trapping possibilities in the Topset, Turbidite, and Ellesmerian-Beaufortian Clastics Plays should also exist within this play. Shales within the play are expected to provide fair to good seals, although their effectiveness may be reduced by faulting and related fracturing.

Both oil and gas seeps are known in the play and six non-economic accumulations have been discovered: Umiat oil field, Gubik gas field, East Umiat gas field, Wolf Creek gas field, Square Lake gas field, and Meade gas field. Approximately 50 exploratory and delineation wells have tested 30 structures in this play. The number of untested structures may be more than 100. The potential for undiscovered oil and gas resources greater than the minimum size used in this assessment is considered good.

Western Thrust Belt Play excerpted from Magoon et. al 1996.
This hypothetical conventional oil and gas play consists primarily of structural traps in Mississippian and Pennsylvanian carbonate reservoirs in the Brooks Range fold-and thrust belt. The northern boundary of the play, guided by seismic reflection data within the NPRA, is drawn far enough north to encompass all of the estimated occurrences of thrust sheets of Lisburne Group carbonates. The southern boundary is arbitrarily placed about 30 mi into the Brooks Range; the area farther south is expected to have negligible petroleum potential based on the observed southward increase in the level of thermal maturity. The western play boundary is the offshore national 3-mile territorial limit in the Chukchi Sea. Greatest potential for petroleum in the Western Thrust Belt Play is expected to be along the immediate range front and foothills to the north. The thickness of rocks in the play may exceed 35,000 ft. The total area of the play is about 16,000 sq mi.

Lisburne Group carbonate rocks are the primary reservoir rock. Other potential reservoir rocks include graywacke sandstone of Jurassic and Cretaceous age and fractured chert and siliceous shale of Mississippian to Jurassic age. The structural style of potential prospects and physical nature of potential reservoir rocks is exemplified by the Lisburne-1 well, which encountered five, 1,200 foot thrust repetitions of the Lisburne Group. Drilling depths range from near-surface to greater than 35,000 ft. Potential source rocks include marine shale of Mississippian to Cretaceous age. Oil shales of Mississippian, Triassic, and Jurassic ages are known to occur within this play, but they are considered representative of local occurrences and not characteristic of the entire play. Preliminary data from the Lisburne-1 well indicate that Jurassic-Triassic rocks are fair to good oil source rocks. Most source rocks are expected to be thermally mature to overmature, although the data are sparse and the geologic relationships complex. The western part of the play displays higher maturity than the eastern part. Bitumen in pores and fractures was encountered in the Lisburne-1 well along with minor indications of gas. Veins of bitumen are known from outcrop localities.

Analysis of paleothermal indicators in the Lisburne-1 well and in the western Brooks Range suggests that thermal maturity results from tectonic burial. A favorable aspect of this situation is that hydrocarbon migration would have been directly into early-formed structural traps. An unfavorable aspect is the duration of deformation, which lasted from

Early Cretaceous to early Tertiary time and may have been episodic or quasi-continuous, thus compromising trap integrity.

Traps in the play are large anticlinal structures composed of multiple thrust sheets of carbonate rocks. Shales within the play are expected to provide fair to good seals, although their effectiveness may be reduced by faulting and related fracturing. Only four exploratory wells have been drilled in this play. Large, untested structures remaining in the play may number in the dozens. The potential for undiscovered oil and gas resources greater than the minimum size used in this assessment is considered fair.

Eagle Creek "Oil Window"

There has been some effort to study petroleum potential in the area southwest of NPRA within the DeLong Mountains and western Brooks Range. The DGGS evaluated the Tingmerkpuk Sandstone, a rockunit that resembles the Kuparuk River Formation. Base camp was set up at Eagle Creek (40 miles north of Red Dog). The purpose of the study was to determine if hydrocarbons were still present. Geologic analysis and mapping was done in 1993-94 and 1996 where programs revealed an area of anomalously low thermal maturity in which the rocks had not been heated as much by burial and mountain building activity compared to the adjacent areas. These cooler areas may represent an "oil window," which is a pressure and temperature regime conducive to the creation and preservation of oil. Further analysis indicated that rocks present are rich oil and gas source rocks compositionally capable of maturation and oil generation. Additionally, geochemical data revealed an area within the "oil window" does contain some extremely rich oil-prone source rocks with as much as 20 percent total organic carbon. Total thickness are unknown (Mickey et. al 1998). The source rocks are of Late Triassic, Early Jurassic, and Early Cretaceous age and are found near the headwaters of Thetis Creek and along the Kukpowruk River. The rocks are over-mature at the Kukpowruk River but could be a source for migrated fluid and gaseous hydrocarbons (Mull 2000).

Geological and geochemical analysis have indicated organic-rich oil and gas-prone Late Triassic, Early Jurassic, and Early Cretaceous source rocks are present in the foothills of the Delong Mountains near the Thetis Creek headwaters. Table 5 shows the results from samples taken from the area. Further studies have indicated that these source rocks are probably structurally overridden to the east by thrust sheets of the northwestern DeLong Mountains (Mull 2000).

Table 5: Geochemical results from rock samples in the western Colville Basin.

Name	Total Organic Carbon (TOC)	Hydrogen Index	TMax	Vitrinite Reflectance (R_o)
Thetis Creek Headwaters	21%	560	420-430	0.6-1.19%
Surprise Creek	4.6%			0.74-1.16%

Red Dog Shale Gas
Further to the south, Red Dog could benefit from shallow gas associated with the Colville Basin. Teck Cominco is conducting a study to determine if shallow, methane gas associated with the Kuna Formation shale beds is large enough to supply the mines' needs for the next 50 years. Coring was done in the area from 1998 to 2000, with over 200 gas content analyses collected and eight geophysical logging sets completed. The resource has been estimated to contain up to 2 Tcf of shale bed gas, however, extraction would be quite costly. Based on the Red Dog Mine's energy use in 2002, it would take over 20 years at 60 Bcf to replace the dependency on diesel fuel. Additionally, it would take between 40 to 60 wells to accomplish that goal (Nelson 2002). The mine is currently prospecting an area about two miles to the north.

Historical Information
Several wells have been drilled within the portion of the Colville Basin that encompasses the planning area. Eagle Creek #1 was drilled by Chevron in February and completed in December 1978. It reached a total depth of 12,049 feet in the Lower Cretaceous. The purpose of the test hole was to test structures in allochthonous rocks of the Brooks Range foothills (Moore and Potter 2003). Gas was recovered in drill stem tests from sandstones within the Nanushuk or Torok formations. The well was plugged and abandoned.

Tungak Creek #1 was drilled by Unocal in December of 1981 and completed in March 1982. The well reached the Torok Formation at its total depth of 8212 feet. The well encountered pooled gas at depth. Gas quantities are similar to those encountered at Wolf Creek, Gubik, Meade, and Square Lake within the NPRA.

Akulik #1 was drilled by Chevron Inc. in April 1981. The well was drilled to a total depth of 17,038 feet. Gas was recovered in drill stem tests from sandstones within the Nanushuk or Torok formations. The well was plugged and abandoned.

Current Production
At this point, little interest has been shown in exploring the portion of the Colville Basin encompassed in the planning area as activities have been focused further east. However, with the continued high prices of petroleum, interest in these plays are likely to increase. The lack of infrastructure will offset exploration, but to what degree is indeterminate. BLM lands within the plays should be considered high potential.

Kotzebue/Hope Basin

Origin and Occurrence
The Hope (aka Kotzebue) Basin is a 700 km long early Tertiary aged basin that extends from the Chukchi Shelf to Wrangel Island north of Russia. The origin of the basin has been attributed to transtensional (the curve in the fault plane moves apart and forms a basin) deformation associated with the left-lateral Kobuk fault. It is one of the longest transtensional faults in the world (Tolson 1987).

Four conceptual plays have been identified by the Minerals Management Service in this basin; Late Sequence Play, Early Sequence Play, Shallow Basal Sand Play, and Seep

Basal Sand Play. All plays come onshore with the exception of the Deep Basal Sand Play. A conceptual play would indicate that it is hypothesized based on the subsurface geologic knowledge of the area.

The Late Sequence Play includes all sediments Oligocene and younger. Reservoir rocks are most likely formed from shallow shelf or fluvio-deltaic sandstones. The estimate of undiscovered potential for the play is projected to contain up to 3341 Bcf of gas and up to 90 Mmb of oil.

The Early Sequence Play comes onshore at the Baldwin Peninsula near Kotzebue and follows the peninsula south approximately 30 miles before veering back offshore into the Kotzebue Sound. The Early Sequence Play consists primarily of Eocene rocks. The test holes that have penetrated this play have revealed highly volcaniclastic rocks indicating some diagenetic processes of porosity destruction. This play is also at considerable depth in contrast to the Late Sequence Play (Oligocene age). Source potential is very poor and thermal maturity was reached in central areas, which are offshore. The estimate of undiscovered potential for the play is projected to contain up to 387 Bcf of gas and up to 11 Mmb of oil (Zerwick 1995).

The Shallow Basal Sand Play were defined to acknowledge the possible existence of sands of which may resemble those found in the Norton Basin. The potential source rocks would include the gas-prone organic material sampled in two onshore wells of the Early Sequence rocks. The Shallow Basal Sand Play is shallower than 10,000 feet and lies laterally apart from the zone of thermally mature strata (Zerwick 1995).

The three conceptual plays should be considered to have low hydrocarbon generation potential. Samples from the Upper and Lower Cretaceous strata in the Waring Mountains yielded Total Organic Carbon (TOC) values that were an order of magnitude lower than typical values from hydrocarbon-rich basins. The values ranged from 0.04 to 0.32 percent with an average of 0.14 percent. The samples had vitrinite reflectance values of 2.0 to 2.5, indicating the thermal alteration to be overmature and outside of the oil and wet-gas window. Oil window vitrinite reflectance values typically range from 0.65 to 1.30 (Decker et. al 1986).

Historical Information

Two hydrocarbon test wells were drilled in the Kotzebue/Hope Basin; Cape Espenberg and Nimiuk Point. Both were drilled in the mid-70s by the Standard Oil Company of California (SOCAL). Cape Espenberg #1 was drilled in 1975 to a total depth of 8,373 feet. The drill hole did not encounter anything that would classify as an oil or gas show, but small indications of methane associated with coalbeds were present in the mudlog. Four formation tests were conducted but recovered only salt and no hydrocarbons (Troutman and Stanley 2002). In both wells, porosities ranged from 40 percent near the top to 5 percent at the bottom. They were determined from compensated gamma-gamma formation density logs of the wells (Decker et. al 1986).

Nimiuk Point #1 was drilled five miles west of the Selawik NWR boundary. The well was bored in the same locality as the conceptual Early Sequence Play. It reached a total depth of 6,311 feet. The well proved largely unsuccessful. A formation test was run between 3,537 and 3,755 feet in which a short blow was observed, but no gas was observed at the surface, making the test inconclusive. Gas zones identified by geophysical well logs were present from 1,130 feet to 1,132 feet, and from 1,158 feet to 1,160 feet, but were determined to be too thin to hold economic quantities of gas, if they in fact do contain gas. The well was abandoned as a dry hole (Troutman and Stanley 2002).

A hole was drilled at Kotzebue in 1950 to test for fresh water. They ran into some high pressure gas at 238 feet, which lifted the heavy string of tools several feet into the air, showering the area with mud and continued to flow for more than 24 hours. The gas may have been biogenic, formed from decaying organic matter (Troutman and Stanley 2002).

In 1973, SOCAL discovered gas at a depth of 90 feet in a seismic shot hole on the Kobuk River Delta, 33 miles southeast of Kotzebue. Samples were taken and results indicated the gas to be 66% methane, 26% nitrogen, 6% oxygen, 2% carbon dioxide, and trace amounts of ethane and higher alkanes. A similar gas show was discovered 5 miles east in the delta at a depth of 65 feet and with similar lab results (Troutman and Stanley 2002).

Oil seeps have been reported within the basin and in the Seward Peninsula area over the years, but these findings were either not investigated by USGS, or, if investigated, have not been confirmed. Additionally, four wells were drilled on the Seward Peninsula near Nome on two separate occasions in 1906 and 1918. The wells were located along Hastings Creek and are very shallow (the deepest reached a total depth of 210 feet). The two wells drilled in 1906 had shows. One well that reached a total depth of 122 feet had a gas show and the other well had an oil show. The gas is believed to be derived from alluvial deposits. The oil show is difficult to explain as the wells were drilled in basement rocks composed of schist and granite. The wells were drilled in response to oil-like films observed on the nearby lagoons and the films brought onshore attached to beach foams (Miller et. al 1959).

Current Production

There are no known formations in the basin that are known to contain oil and gas reservoir rocks. Reservoir quality can only be generalized from geophysical information and stratigraphic relationships. Seismic data indicates trap-producing faults are quite common and could be expected about every 20 km. The downside to this extensive faulting, is that if hydrocarbons are present the fields are likely quite small. With the limited known information, a field equating to 50 – 100 million barrels could be present. Depth of the field could lie somewhere in the 3,000 – 9,000 foot range. More than likely however, the location of this hypothetical field is offshore and would not affect BLM managed lands within the planning area.

Selawik Basin

Origin and Occurrence

The Selawik Basin is located east of the Kotzebue Basin and is considered on some maps to be an extension of the Kotzebue Basin. The Selawik Wildlife Refuge occupies much of the Selawik Basin. The BLM analyzed the refuge in the Selawik National Wildlife

Refuge Oil and Gas Assessment Executive Summary. The document describes the existing geology and the hydrocarbon potential within the refuge. No wells have been drilled in the basin.

Two areas within the refuge boundary have been classified as having moderate oil and gas potential, with the remainder classified as having low potential. The smaller of the two described areas of moderate potential (approximately 800,000 acres) lies along the Kobuk River Valley and the Waring Mountains, just outside of the planning area. The larger of the two areas (approximately 1,100,000 acres) lies along the Selawik River valley and includes the Kobuk River delta. The remainder of the refuge (approximately 1,300,000 acres) has a low hydrocarbon occurrence potential.

In 1987, BLM stated that the Selawik NWR had a low economic and development potential for oil and gas resources. This implies that it is very unlikely that exploration or development will occur in the refuge within the next 25 years, or from 1987 through 2012. Given the current per barrel price of oil, dwindling world supply of hydrocarbon resources and increase in demand for oil and gas, areas designated as having moderate to low potential for development may be reevaluated. Oil and gas leasing is prohibited within the Selawik NWR, and little activity has occurred outside of the refuge.

Historical Information

Oil and gas activity within the basin has been minimal. The area has been geologically mapped by the USGS during the late 1950s and early 1960s, with some additional recent mapping within select areas. There have been no oil or gas wells drilled in the basin.

Current Production

There is no current activity related to oil and gas in the Selawik Basin. Hydrocarbon shows have been located, however the extent of the reserves is unknown. Most of the basin underlies the Selawik NWR, and lack of infrastructure would suggest that there is a low possibility of exploration or development in the Selawik Basin.

D. Geothermal

Alaska contains some of the largest geothermal resources in the United States. However, exploitation of these resources is hindered by the lack of infrastructure and the small size of Alaskan markets (Economides et. al 1983). Geothermal resources of varying temperatures are known to occur throughout the Kobuk-Seward planning area (Figure 9). Thermal springs are produced by subsurface hydrothermal systems, which transfer heat to the surface through fluids, as opposed to through solid rock. Some areas that have been identified include; Clear Creek, Kachauik, Kwiniuk, Pilgrim, Selawik, and Serpentine Hot Springs. Pilgrim Hot Springs is considered a Known Geothermal Resource Area (KGRA), one of three in the State of Alaska. The current law, US Code Title 30, Section 1001(e), defines a KGRA as: " an area in which the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary, engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose."

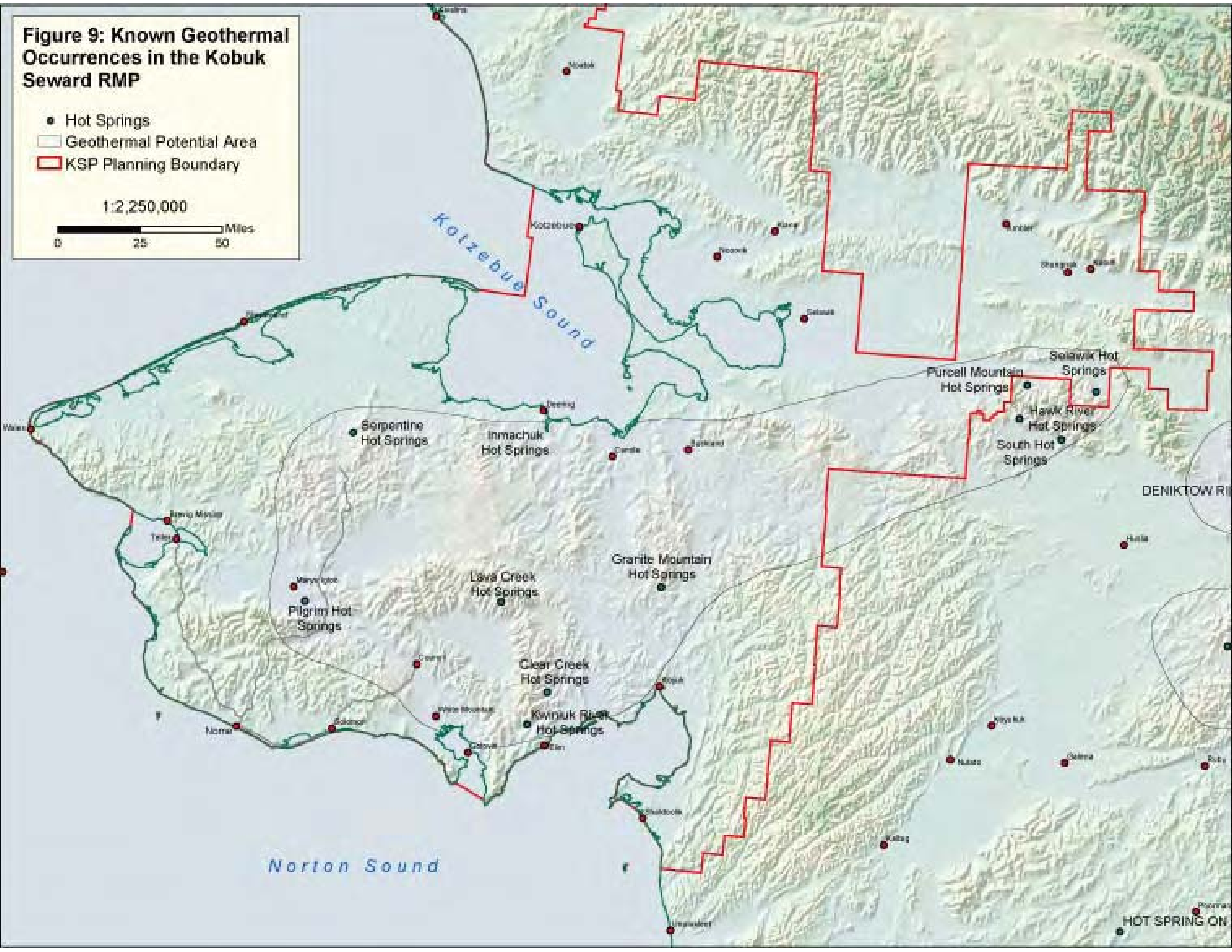

Figure 9: Known Geothermal Occurrences in the Kobuk Seward RMP

Hot springs in western Alaska are typically associated with granitic plutons, or specifically their contact with the surrounding country rock. If the country rock is highly foliated metamorphic rocks then the springs are contained within the pluton. However, if the country rock is sedimentary in nature than the hot springs occur both within the country rock and the pluton (Miller et. al 1973). Of 23 hot springs studied in western Alaska with known bedrock, all are located within at least three miles of a granitic pluton. Distance from plutons can be correlated to the fracturing system present. Well developed “open fracture systems” near the pluton margin allow for the movement of the hot water to the surface (USGS 1970).

Pilgrim Hot Springs

Pilgrim Hot Springs, formerly known as Kruzgamepa Hot Springs, is located on the Seward Peninsula approximately 40 miles northwest of Nome. Access is by air to a small, gravel airstrip or by four-wheel drive vehicle. The Nome-Taylor Highway is seven miles to the east. Pilgrim Springs is located 1/3 of a mile south of the Pilgrim River.

Origin and Occurrence

The hot springs lies in an area 100 yards wide and ½ mile in length. The hot, saline water rises to the surface in an abandoned river channel within the Pilgrim River valley. The valley is bounded by Hen and Chickens Mountain to the north and the Kigluaik Mountains to the south. Of the hot springs on the Seward Peninsula, this is the only one that occurs in the middle of a large alluvial valley (USGS 1971). The springs occur 2 ½ miles north of plutonic and high-grade metamorphic rocks of the Kigluaik Mountains and 2 ½ miles south of low-grade metamorphic rocks of the Hen and Chickens Mountain (Miller et. al 1973).

The springs area has a sandy surface soil and is permanently thawed by the hot water. The hot water tends to seep into the sandy soil below the surface and is only visible in small quantities (about 8 GPM), however the overall flow rate of water emerging at the springs is closer to 67 GPM (Economides et. al 1983). Water temperature averages roughly 156° F, with a maximum of 190° F. The water runs clear with only a slight odor of hydrogen-sulfide (USGS 1971). Chemical analysis of the water is listed in Table 6.

The Pilgrim River Valley is covered with Quaternary alluvium of unknown thickness. The Kigluaik Mountains to the south and the Hen and Chickens Mountain to the north are composed of Precambrian metamorphic rocks. There has been extensive faulting in the area, including a north trending fault that projects 1 ½ miles east of the springs. This fault joins a fault exposed on the Precambrian rocks of the Hen and Chickens Mountain. The extensive faulting network provides the conduits for ascending hot water. The heat source is speculated to be Quaternary volcanism which is present along the major east-west fractures on the Seward Peninsula (Sainsbury et. al 1969). Preliminary Na-K-Ca geothermometry indicates temperatures around 150° C at the reservoir depth.

Table 6: Chemical Analysis of the Water at Pilgrim Hot Springs

	Parts per million (ppm)
Silicon	87
Iron	.7
Aluminum	4.1
Calcium	545
Magnesium	7.4
Sodium	1,587
Potassium	61
Carbonate Radical (CO_3)	0
Bicarbonate Radical (HCO_3)	21
Sulphate Radical (SO_4)	25
Chlorite Radical (Cl)	3,450
Nitrate Radical (NO_3)	0
Borate Radical	Present
Total Dissolved Solids at 180° C	5,955
Temperature	156°
Chemical Character	Sodium-Chloride

Historical Information

Pilgrim Hot Springs or Kruzgamepa Hot Springs, served as a recreation center for miners complete with spa baths, saloon, dance hall, and roadhouse during the early 1900s. The roadhouse and saloon burned in 1908. The property was given to Father Bellarmine Lafortune, who turned the ranch into a mission and orphanage in 1917-18 and operated it until 1941, housing up to 120 children. It served as a home to the orphaned native children during the 1918 influenza pandemic. Ruins of the mission school and other church properties remain at the site, which is still owned by the Catholic Church. The site is listed in the National Register of Historic Places (Alaska Wilderness Guide 1993).

The land was leased to C.T. Phillips who intended to develop the property for geothermal power to Nome and for horticulture purposes (USGS 1971). However, not much else is known as to what work was actually completed.

Two 50 meter test wells were drilled in 1979 with artesian aquifers encountered between 20 – 30 meters. Flow rates were returned between 200 and 400 GPM with temperatures around 90° C (Wescott and Turner 1982). In 1982, the Woodward-Clyde Consultants drilled four additional test wells as well as perforated and tested the two previous wells. The four wells were drilled within a temperature contour where soils at a 15-foot depth exceeded 60° C. The test wells were to serve three purposes; to assist in defining the magnitude and extent of the geothermal resource, to identify the location and nature of the hot water, to serve as geothermal supply wells (Woodward-Clyde Consultants 1983). By conducting analysis based on downhole data, a heat source was located near a depth of 4,875 feet. A fracture has been determined as the conduit that carries the superheated water vertically from 4,875 feet to a depth of 50 feet (Economides 1982). The water then enters an aquifer system and seeps to the surface (Woodward-Clyde Consultants 1983).

Upon completion of the four wells, blank casing was used through the shallow, 50 foot aquifer system so deeper zones could be hydraulically tested. This left the option open as to whether these wells are used for producing deep, fresh water or to plug and perforate to produce high-temperature geothermal waters (Woodward-Clyde Consultants 1983).

Current Production

There is no current production. The development potential is low, but could rate higher if there is an increase in demand for alternative energy sources.

The topographic relief from the hot springs to the Nome-Taylor highway is minor, making an access road relatively simple. The springs lie within a depositional basin containing porous, permeable sediments with adequate surface water that could recharge the reservoirs as the thermal water is removed.

The geothermal resource at Pilgrim Hot Springs could provide power to Nome or aid in mineral development on the Seward Peninsula. Powerlines could be routed through the Cobblestone River Valley, crossing the Kigluaik Mountains at Mosquito Pass then south to Jensens Camp before following the road back to Nome. Distance is about 88 km (Economides 1982).

Serpentine Hot Springs

Origin and Occurrence

Serpentine Hot Springs is located inside the Bering Land Bridge National Preserve. There are two groups of springs approximately ½ mile apart on Hot Springs Creek. Hot water is discharging through the seep at 133 liters per minute with a temperature of 77° C (USGS 1978). Pilgrim and Serpentine Hot Springs have the highest water temperatures of all hot springs in the planning area.

Serpentine Hot Springs are surrounded by tors which give an indication to the past volcanic activity (USGS 1970). The springs occur in the pluton about one mile from a faulted contact. The pluton is made up of biotite granite of the Cretaceous or Tertiary age. The country rock is dated back to the Precambrian (Miller et. al 1973).

History

The area has long been used by the local natives and was recognized for its healthful properties (Alaska Wilderness Guide 1993).

Charles McLennan arrived by dog team in May 1900 and may have been the first non-native to have seen the hot springs. McLennan staked mining claims and raised vegetables for miners who were working claims along the Kougarok River, 10 miles south.

A small settlement and "resort" called Arctic Hot Springs developed and became popular with the miners during the early 1900's.

The airstrip probably dates from the early 1940's and the large cabin sleeping accommodations from the late 1940's. The bathhouse was built by the village of Shishmaref in the mid 1970's.

There was no geothermal energy produced in the past.

Current Production

Despite the high temperature of the hot springs, there is not enough known about the underlying reservoir to determine its size. Additionally, there is no existing infrastructure and the hot springs lies within a National Preserve. Development potential is very low.

Clear Creek Hot Springs

The Clear Creek Hot Springs are located approximately 16 miles north of Elim. The hot springs are located on opposite sides of a Clear Creek tributary with considerable elevation difference between them. The southern spring has a large flow of water, estimated at several hundred gallons per minute with an elevation 400 feet above the valley floor. The temperature is about 63° C. The two northern hot springs have less flow. The upper spring is inaccessible by helicopter and the lower spring has a temperature of 67° C. There is a large elevation differential between the springs. It has been suggested that this occurs because no single structure is permeable enough to discharge all the water in the system. The host rock for the springs is Quartz monzonite of the Darby pluton (Late Cretaceous) which less than a ¼ mile from the contact with the Devonian aged limestone. The pluton-limestone contact is identified as a major fault (Miller et. al 1973).

There is no information on development potential for this site, however, with the current lack of infrastructure or local demand for geothermal energy, development potential should be considered very low.

Hawk River Hot Springs

Hawk River Hot Springs is located just outside of the Planning Area, but is worth considering due to its close proximity. The springs are located roughly 50 miles south-southwest of Kobuk in the east bank of the Hawk River. The spring is at the south end of a 75 x 200 foot clearing and flows directly into the Hawk River. Spring temperatures have been measured above 50° C (Miller et. al 1973).

Bedrock is concealed by alluvium from the river, but based on surrounding geology it is estimated to be hornsfelsic andesite of the Early Cretaceous. Mid-Cretaceous age monzonite of the Hawk River pluton is within ¼ mile of the spring. An east-west fault cuts the pluton at this locale (Miller et. al 1973).

Development potential is very low due to the absence of infrastructure and the overall lack of data regarding the geothermal source.

Inmachuk River Hot Springs

The Inmachuk River Hot Springs are located approximately 25 miles southwest Deering on the Inmachuk River. No data regarding the occurrence, temperature, or characteristics of the springs can be found. Historically, this hot springs was utilized by miners of the early 20th Century gold rush (Murray 2005).

Geothermal development potential of the hot springs is very low, however, the village of Deering wants to construct a 38-mile road to the springs to bring in additional dollars through eco-tourism (Maniilaq Association 2003). An existing 20-mile road (present condition unknown) from Deering to gold mining claims on the Inmachuk River would help provide access (Herreid 1966).

Kwiniuk Hot Springs

The Kwiniuk Hot Springs are located 9 miles northwest of Elim, less than 12 miles from Clear Creek Hot Springs. The single spring occurs about 100 yards north of the Kwiniuk River. Temperatures range between 40° - 50° C. The host rock is the same as for Clear Creek. The spring is in the Darby pluton about 2 miles from the country rock contact. Despite the common pluton between the two hot springs, the two differ substantially in water salinity. Kwiniuk Hot Springs is highly saline in nature, while the Clear Creek Hot Springs are not (Miller et. al 1973).

There is no information on development potential for this site, however, with the current lack of infrastructure or local demand for geothermal energy, development potential should be considered very low.

Kachauik Hot Springs

The Kachauik Hot Springs, also known as Battleship Mountain Hot Springs, are located 20 miles north of Golovin. The spring is located on a small bedrock terrace on the eastern back of the east fork of Cliff Creek. The spring has a distinctive sulfur odor with a temperature of approximately 17° C. The host rock is granodiorite of the Kachauik pluton near its contact with Precambrian schistose marble (Miller et. al 1973).

There is no information on development potential for this site, however, with the current lack of infrastructure or local demand for geothermal energy, development potential should be considered very low.

Lava Creek Hot Springs

Lava Creek Hot Springs is located about 50 miles north of Golovin on the south side of the Bendeleben Mountains. The spring is located approximately 100 feet above the valley floor. Flow rate was not measured, however was indicated as a strong flow. The water temperature ranges from 60° - 65° C. The springs have a distinct sulfur odor. The spring occurs near the contact between the Late Cretaceous quartz monzonite of the Bendeleben pluton and the Precambrian country rocks. The valley floor below the springs is underlain by Quaternary age basalt (Miller et. al 1973).

There is no information on development potential for this site, however, with the current lack of infrastructure or local demand for geothermal energy, development potential should be considered very low.

Purcell Mountain Hot Springs

The Purcell Mountain Hot Springs are located 44 miles south-southwest of Kobuk just outside of the Planning Area. The springs occur on the north bank of an unnamed tributary to the Shinilikrok Creek, which is located about 5 miles northeast of Purcell Mountain. The spring is small and has a temperature between 15° and 20° C (Miller et. al 1973).

The spring occurs in a Late Cretaceous hypabyssal volcanic complex that is made up of flows, tuffs, and intrusive rocks. The spring is approximately ¼ mile from the contact with Lower Cretaceous andesite and in a relative proximity to a granitic pluton (Miller et. al 1973).

Due to the low temperatures and the absence of infrastructure, it is very unlikely any development would occur during the life of the plan.

Selawik Hot Springs

Selawik Hot Springs, also known as Souby or Davidson Hot Springs is located 38 miles south of Kobuk. The springs are divided into upper and lower pools. The upper portion is located outside, but near the boundary of the Selawik Wildlife Refuge and the lower springs are within the Refuge. The springs occur approximately 2 miles apart at the headwaters of a tributary to the Selawik River. There are large open meadows approximately 1,000 x 200 yards; the largest area of thawed ground for any spring in western Alaska. The temperature is estimated between 50° and 60° C (Miller et. al 1973).

Both sets of springs occur in Lower Cretaceous andesite near a prominent N 70° W trending lineament. The spring source is located 1 ½ miles north of a quartz monzonite of the Wheeler Creek pluton (Miller et. al 1973).

Due to its close proximity to the Selawik Wildlife Refuge and lack of infrastructure, development potential should be considered very low for the life of the plan.

South Hot Springs

The South Hot Springs are located just outside of the KSP Planning Area boundary roughly 52 miles south of Kobuk. Several springs occur along a west-facing timbered slope 200-400 feet above an unnamed tributary to the Hawk River. Water temperature is estimated to be 50° C (Miller et. al 1973).

The hot springs occur in quartz monzonite of the Wheeler Creek pluton of the Late Cretaceous. The contact point is within ¼ mile of the Lower Cretaceous andesite. The springs have been noted to be trending on a N 80° W lineament (Miller et. al 1973).

IV. RECOMMENDATIONS

The intention of this report is to identify areas of high development potential for leasable minerals that could become an area of interest to industry during the life of the plan (Table 7). Rankings given in this report are based solely on documented literature and BLM's interpretations of their conclusions.

Table 7: Resource Development Potential based on Geographic Locations

	Kobuk River Valley	North Slope	Nulato Hills	Seward Peninsula
Coal	L	H	L	M
Coal Bed Natural Gas	L	H	L	L
Oil and Gas	L	L	L	L
Geothermal	L	L	L	L

It is the recommendation of this report to further study those areas of having coalbed natural gas potential or those areas of oil and gas potential. Coal will not be examined in the ensuing RFD as it will be addressed in an amendment to the EIS if leasing requirements are met in 43 CFR 3420.1-4. Geothermal will not be addressed as the development potential is low despite a moderate occurrence ranking in Table 1.

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