Appendix G

Mineral Potential Report

MINERAL POTENTIAL REPORT

RING OF FIRE PLANNING AREA, ALASKA

Prepared for

BUREAU OF LAND MANAGEMENT

ANCHORAGE FIELD OFFICE

Prepared by

URS CORPORATION

ANCHORAGE, ALASKA

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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
ADN	Anchorage Daily News
ADNR	Alaska Department of Natural Resources
AEIDC	Arctic Environmental Information Data Center
AFO	Anchorage Field Office
AGI	American Geological Institute
AMIS	Alaska Minerals Information Service
AMRAP	Alaska Mineral Resource Appraisal Program
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
AOGCC	Alaska Oil and Gas Conservation Commission
ARDF	Alaska Resource Data File
ASTM	American Society of Testing and Materials
AVO	Alaska Volcano Observatory
BLM	Bureau of Land Management
Btu/lb	British thermal unit per pound
CBNG	coalbed natural gas
CFR	Code of Federal Regulations
CNF	Chugach National Forest
DGGS	Division of Geological & Geophysical Surveys
FEIS	Final Environmental Impact Statement
ft	foot/feet
KGRA	known geothermal resource area
KMDA	Known Mineral Deposit Area
lb	pound
MAS/MILS	Mineral Availability System/Mineral Industry Location System
MEA	Matanuska Electric Association
MEP	Mineral Exploration Potential
MMBO	million barrels of oil
MMS	Minerals Management Service
MW	megawatt
NEPA	National Environmental Policy Act
NPS	National Park Service
NURE	National Uranium Resource Evaluation
NWR	National Wildlife Refuge
PGE	platinum group metals
PRMP	Proposed Resource Management Plan
PWS	Prince William Sound
RASS	Rock Analysis Storage System
RDI	Resource Data Center, Inc.
REE	rare earth elements
RFD	Reasonable Foreseeable Development
scf	standard cubic feet
S-P	self-potential
TCFG	trillion cubic feet of gas
TNF	Tongass National Forest

ACRONYMS AND ABBREVIATIONS

URS	URS Corporation
U.S.	United States
USBOM	U.S. Bureau of Mines
USDOE	U.S. Department of Energy
USDOI	U.S. Department of the Interior
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VMS	volcanic massive sulfide

1.0 INTRODUCTION

Presented in this document are the results of a Mineral Potential Assessment conducted for the United States (U.S.) Department of Interior (USDOI), Bureau of Land Management (BLM) for the Ring of Fire planning area in southern Alaska. This document has been prepared by URS Corporation (URS) as part of BLM Contract No. GS.10F.0105K for completion of the Proposed Resource Management Plan (PRMP) and Final Environmental Impact Statement (FEIS) for the Ring of Fire planning area.

The Ring of Fire planning area spans a linear distance of 2,500 miles extending from the Aleutian Islands at the southwestern tip of Alaska, through the Alaska Peninsula, parts of southcentral Alaska, and through the southeast panhandle of Alaska (Figure G-1). The planning area is divided into four geographic regions: 1) Alaska Peninsula/Aleutian Chain, 2) Kodiak, 3) southcentral, and 4) southeast regions. The southcentral region includes the Cook Inlet area, Matanuska-Susitna Valley, and Kenai Peninsula, but excludes the eastern Prince William Sound (PWS) area and the Wrangell Mountains to the east. The southeast region extends from Yakutat Bay to the southeastern tip of Alaska.

1.1 Lands Involved and Land Status

BLM-managed surface lands within the Ring of Fire planning area include lands held by BLM, as well as lands selected by the State of Alaska and Native corporations that have not yet been conveyed, referred to as state-selected and Native-selected lands. State lands in Alaska came about through the Alaska Statehood Act of 1959, which gave the new state selection rights to federal land to foster development and state independence, a process that was supposed to end in 1984. Native lands were designated as a result of the Alaska Native Claims Settlement Act (ANCSA) of 1971, which superceded the Statehood Act and provided for Native claims to traditional lands. ANCSA and the Alaska National Interest Lands Conservation Act (ANILCA) of 1980 froze state selection rights to previously open federal lands. ANILCA granted a ten-year extension to complete the state-selection process by 1994. Most areas of known high mineral potential within the Ring of Fire planning area were selected and conveyed as a result of these actions.

During the land-selection process, both the state and Native organizations were allowed to overselect beyond their legal entitlement. Selections are being relinquished regularly. Thus, not all of the selected lands in the Ring of Fire planning area will be conveyed over the next 10 to 15 years. Some will be retained by BLM.

ANCSA authorized the withdrawal of federal lands from development in order to protect the public interest and create potential conservation units such as national parks, forests, and wildlife refuges (referred to as D-1 and D-2 lands). D-2 land withdrawals resulted in the introduction of ANILCA, under which many of the conservation units were established. Land withdrawals are still in effect for all remaining BLM-managed surface lands within the Ring of Fire planning area, which have restricted mining development since the early 1970s. Under the Ring of Fire PRMP/FEIS, land withdrawals may be revoked or modified based on studies that will determine their proper classification. Thus, all BLM lands are addressed in this report regardless of land withdrawal status.

BLM is responsible for administering subsurface minerals on BLM surface lands, as well as on split estate lands in which BLM owns the subsurface mineral rights, but the surface is owned by another government agency or is privately held. Federal split estate lands within the Ring of Fire planning area include U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and Department of Defense (military) lands. Mineral development and surface activities on federal split estate lands are managed by the appropriate surface agency, but BLM is responsible for administrative functions such as mining claim filings, adjudications, and record keeping (Cody 1995; Nichols 1999; Persson 2004).

Land status within the Ring of Fire planning area is depicted on Figures G-2 through G-5. BLM-managed surface lands greater than 320 acres or one-half of a section are shown. Those less than 320 acres are not shown and are unavailable at this time. There are thousands of unknown BLM-managed surface parcels scattered throughout the planning area.

1.2 Minerals Addressed

Mineral resources on BLM-managed surface and subsurface lands are divided into three categories based on provisions of various mining laws. These are referred to as “leasable,” “locatable,” and “salable” minerals, which are each addressed in Chapters 3 and 4 of this report.

In the late 1800s, the USDOI began to define hardrock minerals as “locatable” if they could be found on public lands in quantity and quality sufficient to make the land more valuable by their existence (BLM 2004d; ENSR *et al.* 2003). The General Mining Law of 1872 established the authority for locatable mineral mining claims, and provided the basis for subsequent mining laws that, over time, substantially reduced the number of minerals considered locatable. Two primary laws, the Mineral Leasing Act of 1920 and the Materials Act of 1947, excluded certain mineral types that could only be acquired through a federal leasing program or disposed of by sale. Leasable minerals include oil and gas, coalbed natural gas (CBNG), geothermal fluids, and certain solid minerals such as potassium, sodium, phosphate, and oil shale. Salable minerals include common varieties of mineral materials such as construction aggregate (sand and gravel), building stone, pumice, clay, and limestone. Mineral types remaining in the locatable category following these modifications include metallic and certain nonmetallic industrial minerals generally found in lode or placer deposits (BLM 2004d; ENSR *et al.* 2003; Nichols 1999). Under certain circumstances, mineral materials can be considered locatable minerals.

1.3 Scope and Objectives

The objective of the Mineral Potential Assessment is to evaluate mineral potential within the Ring of Fire planning area at an intermediate level of detail as specified in BLM Manual 3031 (BLM 1985), for the purpose of making planning decisions in the PRMP/FEIS. BLM actions that require an intermediate level of detail include those that restrict mineral exploration and development, or that withdraw lands from mineral entry or leasing. Consequently, this report has been prepared as a preliminary mineral assessment, and is intended for use in preparation of the FEIS as required by the National Environmental Policy Act (NEPA) of 1969, and for use in the development of the PRMP for the BLM Anchorage Field Office (AFO). It is intended to be broad enough to apply to both known and unknown lands under BLM jurisdiction, but is not intended to be a comprehensive analysis of mineral potential for individual land parcels within the Ring of Fire planning area.

1.4 Occurrence and Development Potential

Mineral potential assessment requires understanding of two components, the potential for mineral occurrence and the potential for their economic development. The potential for mineral occurrence is a prediction of the likelihood of the presence of these resources. Occurrence potential does not necessarily imply that the mineral can be economically exploitable, or that the quality and quantity of the resource is known. Whenever known, however, the current and projected development potential is part of the mineral resource assessment. Development potential describes whether or not a mineral occurrence is likely to be explored or developed within the next 10 to 15 years under given geologic and nongeologic assumptions and conditions (BLM 1985).

Occurrence and development potential of each mineral resource category are discussed in Chapters 3 and 4 of this report, respectively. Development potential requires the projection of Reasonable Foreseeable Development (RFD) per BLM guidance (BLM 1990). RFD scenarios have been prepared by BLM geologists, and are provided in Attachments A and B and summarized in Chapter 4 of this Appendix. While development potential for leasables applies to both BLM-managed surface and split estate lands, BLM does not actively manage locatable or salable minerals on split estate lands. For example, on USFS land, locatables are managed by the USFS and BLM maintains records only. Thus, the description of development potential for locatables and salables in Chapter 4 is intended to apply only to BLM-managed surface lands.

1.5 Report Organization

The main body of this document is divided into three chapters. Chapter 2 provides a description of the geologic setting of each region in the Ring of Fire planning area, including rock units, structural geology, and other data that are available to provide an understanding of the resource. Chapter 3 describes known or suspected mineral deposits within each mineral category, history of past production, and criteria used in the development of occurrence potential maps. Chapter 4 provides discussion of development potential for each mineral category. Recommendations and references are provided in Chapters 5 and 6, respectively.

2.0 DESCRIPTION OF GEOLOGY

2.1 Physiography

2.1.1 Alaska Peninsula/Aleutian Chain Region

The Alaska Peninsula/Aleutian Chain region of the Ring of Fire planning area encompasses the extreme southwest portion of the state (Figures G-2 and G-3). Bounded by the North Pacific Ocean to the south and the Bering Sea to the north, the Aleutian Chain portion of the region extends in an east-west arc for over 1,000 miles from the Kamchatka Peninsula of Russia to the Alaska Peninsula. The Aleutian Chain consists of many islands ranging from 20 to 60 miles wide, which represent volcanic summits of a submarine ridge. One of the most seismically and volcanically active areas in the world, the region contains 57 volcanoes, of which 27 are reportedly active, and rise to elevations between 2,000 and 9,400 feet (ft) above sea level. The topography features glaciated and rubble-strewn volcanic cones, indented with fjords and bordered by sea cliffs or wave-beaten platforms (USFWS 1988; Nowacki *et al.* 2002; Selkregg 1974b).

The Alaska Peninsula divides Bristol Bay from the North Pacific Ocean. The peninsula extends for approximately 400 miles from Bechevin Bay at the beginning of the Aleutian Islands arc to the base of the peninsula near Mount Katmai (USFWS 1985). The Aleutian Range, which forms the backbone of the peninsula, reaches elevations of 4,500 to 8,500 ft, and is mantled on its northwest side by the Nushagak-Bristol Bay Lowland (Selkregg 1974b; Warhaftig 1965). The Alaska Peninsula is about 100 miles wide at its base, and narrows progressively toward the southwest as the range becomes increasingly submerged. The peninsula is characterized by rugged mountain terrain, lake-dotted tundra, and many rivers. Pleistocene glaciation has produced topographies that range from smooth glacial moraines and colluvial shields on the north side of the peninsula, to deeply cut fjords on the south side (Nowacki *et al.* 2002; Selkregg 1974b).

2.1.2 Kodiak Region

The Kodiak region of the Ring of Fire planning area includes Kodiak Island and all surrounding islands that lie across Shelikof Strait from the Alaska Peninsula (Figure G-3). The Kodiak archipelago is approximately 180 miles long by 70 miles wide. Kodiak Island is mountainous and intensely scoured and eroded by repeated Pleistocene glaciations. The island is characterized by high peaks with cirque glaciers and low rounded ridges surrounding glacially scoured valleys. The Kodiak Mountains reach elevations of 2,000 to 4,000 ft, and are generally drained by short swift streams. The northern part of Kodiak Island is characterized by rocky, glacially carved fjords, while the southern coastline is relatively smooth with few indentations (Nowacki *et al.* 2002; Selkregg 1974a; USFWS 1987).

2.1.3 Southcentral Region

The southcentral region of the Ring of Fire planning area encompasses a wide variety of land types surrounding the Cook Inlet Basin (Figure G-4). This region includes the eastern slopes of the northern Aleutian Range, the foothills of the southern and central Alaska Range, the Matanuska-Susitna Valley, the western part of the Talkeetna Mountains, the Chugach Mountains located between Anchorage and Valdez, the island fjords of western PWS, and the Kenai Peninsula.

The north end of the Aleutian Range merges imperceptibly with the southern end of the Alaska Range. Several active volcanoes, including Augustine, Illiamna, Redoubt, and Mount Spurr, lie in this area, reaching elevations over 10,000 ft. The northwest corner of the southcentral region is composed of foothills of the central Alaska Range, which are drained by the Yentna and Skwentna Rivers, major tributaries to the Susitna River. The ice-carved Talkeetna Mountains in the northeast corner of the region sustain several glaciers and rise to elevations of 6,000 to 7,000 ft (Selkregg 1974a; Wahrhaftig 1965).

The Cook Inlet-Susitna Lowland extends for over 200 miles through the center of the southcentral region. Together with the Upper Matanuska Valley, these gently-sloping lowlands were buried by ice and flooded by proglacial lakes several times during the Pleistocene. Numerous lakes, ponds, and wetlands associated with glacial tills and outwash deposits exist throughout this area. The lowlands are fed by multiple drainages that originate in the mountains of the Alaska Range and the Talkeetna and Chugach Mountains. Several of these drainages, including the Susitna, Matanuska, and Knik Rivers, are large, glacially fed rivers with heavy sediment loads that course down mountain ravines and braid across valley bottoms and coastal flats (Nowacki *et al.* 2002; Wahrhaftig, 1965).

The Chugach Mountains extend east of Anchorage and across the north side of PWS. Along PWS, these mountains form steep angular peaks with elevations in the range of 12,000 to 13,000 ft, that are surrounded by large icefields, snowfields and glaciers, some of which extend down to tidewater. Western PWS and the southern portion of Kenai Peninsula are characterized by a fjordal coastline, which formed where glacier-carved terrain filled with seawater after deglaciation. Broad U-shaped valleys with deeply incised sidewalls lie at the heads of many of the fjords (Nowacki *et al.* 2002). The Kenai Mountains form the central and eastern portions of the Kenai Peninsula. These moderately high, rugged mountains are covered with icefields, snowfields, and glaciers (Nowacki *et al.* 2002; Wahrhaftig 1965).

2.1.4 Southeast Region

The southeast region of the Ring of Fire planning area encompasses all of southeast Alaska from Yakutat Bay to the southeastern border with Canada (Figure G-5). This island-rich fjordland formed when the glacier-carved landscape filled with seawater after deglaciation. Broad U-shaped valleys with steep sidewalls are common at the heads of fjords. Rounded mountains with rolling till plains occur where continental and piedmont glaciers overrode the land. High, steep-sided, angular mountains exist above the upper reaches of the glaciers. The St. Elias Mountains east of Yakutat Bay reach elevations of 14,000 to 19,000 ft. South of the St. Elias Mountains, the Boundary Ranges, which form the eastern border with Canada comprise a glacier-covered upland between 5,000 and 10,000 ft (Nowacki *et al.* 2002; Selkregg 1974c).

Lush temperate rain forests blanket the shorelines and mountain slopes of this region. Open and forested wetlands occur on poorly drained soils, especially where they overly compact glacial tills, marine terraces, and gentle slopes. A narrow coastal plain lies along the Gulf of Alaska coast between Yakutat Bay and Chichagof Island (Nowacki *et al.* 2002; Wahrhaftig 1965).

2.2 Structural Geology and Tectonics

The Ring of Fire planning area spans one of the most tectonically active areas of the world. Major fault systems along the southern edge of the Ring of Fire planning area form the boundary between the North American Plate to the north and east, and the Pacific Plate to the south. The entire region has been dominated by large-scale plate convergence or oblique convergence since the Late Triassic. Manifestations of this plate interaction include development of the Aleutian volcanic arc and oceanic trench, the major right-lateral Fairweather fault system of the southeast region, extreme uplift and topographic relief on coastal mountains throughout the Ring of Fire planning area, and some of the most active seismicity and largest earthquakes in the world (Pflafker and Berg 1994).

2.2.1 Alaska Peninsula/Aleutian Chain Region

The Alaska Peninsula/Aleutian Chain region forms an arcuate arrangement of mountain ranges and submerged margins, encompassing two different geologic segments that meet near Unimak Pass off the southwestern tip of the Alaska Peninsula (Figures G-6 and G-7). The Aleutian Ridge segment lies west of Unimak Pass and is geologically younger than the Alaska Peninsula, having no pre-Eocene rocks (Vallier *et al.* 1994). The Aleutian Ridge is a mostly submerged mountain range that formed by the subduction of the Pacific Plate underneath the North American Plate along the Aleutian Megathrust. This major south-dipping decollement fault system surfaces near the bottom of the Aleutian Trench in the Pacific Ocean about 100 miles south of the islands. The average depth of megathrust earthquakes beneath the Aleutian Chain is on the order of 60 miles (Plafker *et al.* 1993).

The Alaska Peninsula segment lies east of Unimak Pass and consists of the peninsula, its adjacent islands, and submerged margin. The Aleutian Megathrust is responsible for active seismicity beneath the peninsula at depths ranging from 45 to 100 miles. A number of northeast-trending surface faults occur along the southeast coast of the peninsula, including the suspected active Chignik and Hallo Creek Faults in the vicinity of Chignik Bay and Mount Katmai, respectively. Additionally, the suspected active Bruin Bay Fault trends northeasterly through the center of the northern peninsula, separating Cenozoic deposits to the northwest from older rocks of the Peninsular Terrane to the southeast (Plafker *et al.* 1993; Siberling *et al.* 1994).

2.2.2 Kodiak Region

The Kodiak region is composed primarily of Chugach terrane rocks that are bounded on both sides by major northeast-trending and northwest-dipping thrust fault systems. Geologically, the Kodiak area is an extension of Kenai Peninsula, as they share the same rocks and structures (Figure G-7) (Beikman 1980; USFWS 1988). The Border Ranges Fault along the northwest coast of Kodiak Island separates Chugach terrane from Peninsular terrane rocks to the northwest. The Contact Fault lies along the southeast coast of Kodiak, is suspected to be active, and separates Chugach terrane rocks from younger slivers of Ghost Rocks terrane and Prince William terrane (Plafker *et al.* 1994; Siberling *et al.* 1994).

The Aleutian Megathrust lies beneath the Kodiak region at depths of about 20 to 25 miles, and surfaces in the Aleutian Trench about 70 miles southeast of Kodiak. Additional known active surface faults occur along Kodiak Shelf between the island and trench. The Kodiak region lies within the rupture zone of the 1964 Alaska earthquake, which originated along the megathrust approximately 250 miles to the northeast. Kodiak Island experienced approximately 1 to 5 ft of subsidence during this event (Plafker *et al.*1994).

2.2.3 Southcentral Region

The structural geology of the southcentral region is composed of a complex series of subparallel strike-slip and/or thrust fault systems and intervening arcuate-shaped rock terranes of various ages. Mesozoic Peninsular terrane rocks underlie the northeast part of the Alaska Peninsula, the southwest coast of Cook Inlet, and the Talkeetna Mountains. These rocks, overlain by Cenozoic strata of Cook Inlet Basin and the Susitna Valley, are bounded to the southeast by the regionally extensive, arcuate Border Ranges fault system. This fault system extends from Kodiak through the southcentral region, where it curves around to the east and eventually arcs towards the southeast region (Plafker *et al.* 1994).

The Border Ranges fault system separates Peninsular terrane from Chugach terrane rocks of Kenai Peninsula and the Chugach Mountains (Siberling *et al.* 1994). Chugach terrane rocks are separated from younger slivers of Prince William and Ghost Rocks terranes along eastern Kenai Peninsula and northern PWS by the regionally extensive Contact Fault (Plafker *et al.* 1994; Siberling *et al.* 1994).

In the Susitna Valley area, the active Castle Mountain Fault generally separates Peninsular terrane and Cook Inlet Basin strata from Kahiltna and Wrangellia terranes to the northwest. The Castle Mountain Fault merges with the Bruin Bay Fault along western Cook Inlet, which extends into northern Alaska Peninsula (Plafker and Berg 1993; Nokleberg *et al.* 1994; Siberling *et al.* 1994).

Much of the southcentral region lies within the rupture zone of the 1964 Alaska earthquake, experiencing subsidence and uplift ranging from -6 ft along eastern Kenai Peninsula to +10 ft in southwestern PWS (Plafker and Berg 1994). Active seismicity along the megathrust lies at depths of approximately 20 to 30 miles beneath Kenai Peninsula, the Matanuska-Susitna Valley, and Chugach Mountains; and is up to 60 miles deep along the west side of Cook Inlet.

Folding and reverse faulting of Cenozoic strata is suspected to be actively occurring throughout Cook Inlet Basin as a result of the oblique convergent tectonics of the region (Haeussler *et al.* 2000). Many of these features form traps for oil and gas fields in the Cook Inlet Basin (Section 3.1.1).

2.2.4 Southeast Region

The rocks of the southeast region were emplaced in the Alexander Archipelago during a series of subductions and accretions by tectonic plates obliquely colliding with the ancient continental margin of western North America from Jurassic to early Tertiary time (Gehrels and Berg 1992 and 1994). The region is dominated by a series of north-northwest-trending, active or suspected active, right-lateral fault systems that separate subcontinental blocks of accreted terranes, and intervening shorter northwest-trending faults within terranes (Figure G-9). Many of these faults have provided preferential pathways for glaciation, which has formed deeply carved valleys and fjords throughout the southeast region. Deformation during successive accretions also resulted in regional metamorphism (Gehrels and Berg 1992; Baichtal and Swanston 1996), providing a rich setting for metalliferous minerals (Section 3.2.3.4).

The active Fairweather Fault lies offshore of most of the southeast region, trending onshore at Icy Cape and east of Yakutat, where it merges with the Contact fault system of the southcentral region. The Fairweather Fault separates Yakutat terrane at the northeast apex of the Pacific Plate, from older Chugach terrane rocks along the west edge of the North American Plate. The Yakutat terrane is currently moving with the Pacific Plate, and is colliding with the North American Plate along the Fairweather Fault (Bruns 1996a, Bruns 1996b). Earthquakes greater than magnitude 7.0 occurred along the Fairweather Fault in 1949, 1958, and 1972. Two short faults east of Yakutat that are subparallel to the Fairweather Fault are the suspected source of the Yakutat Bay Earthquakes of 1899 (Plafker *et al.* 1993).

Paleozoic and Mesozoic-aged Alexander terrane rocks lie along the eastern boundary of the Chugach terrane throughout the southeast region (Siberling *et al.* 1994). The boundary between the two terranes is marked by inactive faults to the north, and the suspected active Peril Strait and Chatham Strait Faults to the south. The Chatham Fault extends north-northwesterly through Alexander Terrane into the northeast corner of the southeast region, where it is continuous with the active Denali Fault of interior Alaska (Gehrels and Berg 1992 and 1994; Plafker *et al.* 1993). The Denali Fault was the epicenter of the magnitude 7.9 Denali Earthquake of 2002.

Slivers of Wrangellia terrane and Gravina-Nutzotin belt rocks occur along the west and east sides of the Alexander terrane, respectively. Taku terrane rocks lies east of both the Alexander terrane and Gravina belt, separated by the Denali Fault at the north end of the region, and by numerous northwest-trending inactive faults throughout central and southern the southeast region (Gehrels and Berg 1992 and 1994; Siberling *et al.* 1994; Plafker *et al.* 1993). Post-accretionary plutonic rocks intrude both Taku and Stikinia terrane strata along the eastern border of the southeast region with Canada, and are separated from Taku terrane rocks by the Coast Range megalineament (Gehrels and Berg 1992).

2.3 Historical Geology and Rock Units

2.3.1 Alaska Peninsula/Aleutian Chain Region

Aleutian Chain. The Aleutian Chain, geologically the youngest region in Alaska, is dominated by Tertiary and Quaternary volcanic rocks that form the crests of a submarine volcanic arc (Beikman 1980; USFWS 1988) (Figures G-2 and G-6). The Aleutian arc formed since Eocene time along zones of convergence between the North American Plate and various oceanic plates, including the modern day Pacific Plate and the extinct Kula Plate. The first major growth of the Aleutian Ridge occurred after a rotational change in the Kula Plate during the Eocene. The ridge was subsequently eroded and experienced renewed volcanism since the Oligocene (Vallier *et al.* 1994).

Figure G-10 presents a stratigraphic column of sedimentary and volcanic formation names of the Aleutian Chain. Most of the islands are underlain by Cretaceous or Lower Tertiary basement rocks consisting of basalt and andesite lava flows and tuffs (Selkregg 1974b; Vallier *et al.* 1994). Metamorphosed mafic plutonic rocks comprise a portion of the Eocene basement rocks on Attu, and younger intrusive rocks of felsic to intermediate composition outcrop in the central and eastern Aleutians. Lower to Middle Tertiary marine interbedded sedimentary and volcanogenic strata have been identified in the vicinity of Attu and Amchitka Islands in the western Aleutians, and on Unalaska Island in the eastern Aleutians. These units include primarily volcaniclastic debris flows, turbidites, and sandstone (Vallier *et al.* 1994).

Most of the active volcanoes of the Aleutian arc are stratovolcanoes or composite cones, which are characterized by steep slopes, dike swarms radiating from the center, and parasitic cones and vents on the flanks of the main volcano (USFWS 1988; Wohletz and Heiken 1992). Older volcanoes of the Aleutians include both stratovolcanoes and shield volcanoes, characterized by thin flows and gentle slopes. Many of the Aleutian volcanoes also contain calderas of former collapsed volcanoes (USFWS 1988).

Unconsolidated surficial deposits of the Aleutian Chain include volcanic ash, pumice, cinders, and alluvium, as well as deposits of glacial origin. Glaciation is responsible for the presence of till, meltwater outwash, and loess (USFWS 1988).

Alaska Peninsula. Since the early Eocene, the entire Aleutian arc, including the Alaska Peninsula, has shared a similar geologic history. Prior to the Eocene, however, the evolution of the Alaska Peninsula was different from the rest of the Aleutian arc. Parts of the Alaska Peninsula may have originated as an island arc far to the south of their present position, and were accreted onto the rest of Alaska during Late Cretaceous and earliest Tertiary time. The Aleutian-Alaska Range batholith, which forms the backbone of the Alaska Peninsula, was emplaced in the Jurassic prior to accretion. Late Cretaceous strata of the Alaska Peninsula (Figure G-7) were formed from detritus of the eroded batholith and earlier Mesozoic formations. Volcanism and magmatism occurred over several episodes along the peninsula during the Tertiary, and sedimentary rocks of this period contain many volcaniclastic sequences. Folding and development of en echelon anticlines occurred in the central Alaska Peninsula during the middle Tertiary (Nokleberg *et al.* 1994; Vallier *et al.* 1994). Tertiary strata of the northwest side of the peninsula are gently deformed and rest on Jurassic basement (Molenaar 1996a, Molenaar 1996b). Numerous late Tertiary granitic stocks intrude the sedimentary section, and volcanism during the Quaternary resulted in a chain of stratocones along the peninsula (Miller and Richter 1994; Molenaar 1996a; Molenaar 1996b).

The present day configuration of rock units on the peninsula can be divided into two distinct areas that are split down the center of the peninsula by the inferred extension of the Bruin Bay Fault (Section 2.2.1, Figure G-7): 1) the mountainous southeastern half consists of folded Mesozoic to Tertiary sedimentary rocks and Quaternary volcanoes; and 2) the alluvial-covered lowland of the northwest half is underlain by Tertiary sedimentary rocks that thicken to the northwest under Bristol Bay. Mesozoic strata on the southeast side of the peninsula include Triassic limestone and shale; and a number of marine and nonmarine graywacke, sandstone, and shale formations of Jurassic and Upper Cretaceous age, including the coal-bearing Chignik Formation (Figure G-10) (Burk 1965; Merritt and Hawley 1986). Limestones of the Upper Triassic Kamishak Formation have been the focus of oil exploration activities in this area (Molenaar 1996a; Molenaar 1996b) (Section 3.1.1.1). Early Tertiary strata of the Alaska Peninsula include volcaniclastic siltstone, sandstone, and conglomerate of the Tolstoi and Belkoski Formations. Middle Tertiary rocks consist primarily of mudstones, siltstones, and sandstones with intercalated coals, which were laid down in swampy to marine environments (Stepovak, Meshik, and Bear Lake Formations). Marine sandstone and conglomerate comprise the Pliocene Tachilni Formation (USFWS 1985).

Surficial deposits on the Alaska Peninsula are mostly of glacial, fluvial, and volcanic origin. The eastern slopes of the Aleutian Range are generally free of surficial cover, while the gentler northwest slopes and Bristol Bay lowlands contain a thick blanket of unconsolidated material, including volcanic ash, pumice, cinders, glacial till, morainal deposits, outwash, and alluvium. Sand, silt, and gravel are found on beds and terraces of modern floodplains and meltwater streams. Fine-grained glaciolacustrine deposits occur along some of the larger lakes, and slope wash deposits are found at the base of volcanoes (USFWS 1988; Selkregg 1974b).

2.3.2 Kodiak Region

Like the Alaska Peninsula, the Kodiak region evolved along a zone of plate convergence since at least the Jurassic. The various rock terranes of the Kodiak region, including the Peninsular, Chugach, and Prince William Terranes, originated far to the south of their present position, and were accreted during the Late Cretaceous and Lower Tertiary through intermittent subduction-related offscraping of oceanic deposits. The Border Ranges Fault along the northwest side of the Kodiak region was initiated prior to accretion, and forms the boundary between the Peninsular and Chugach terranes (Plafker *et al.* 1994; USFWS 1987; Vallier *et al.* 1994).

Chugach and Prince William terrane rocks are generally younger than those of the Peninsular terrane, and consist largely of fine-grained clastic and volcanic rocks deposited in deep marine settings (e.g., Uyak Complex, Kodiak Formation, Ghost Rocks Formation, and Sitkalidak Formation, Figure G-11). Granitic intrusive rocks invaded the upper Cretaceous Kodiak Formation during Paleocene time. Middle to Upper Tertiary strata along the southeast side of the Kodiak region (e.g., Sitkinak, Narrow Cape, and Tugidak Formations) record progressive tectonic uplift in the region, a decrease in volcaniclastic rocks, and an increase in strata of glaciomarine origin (Vallier *et al.* 1994; Siberling *et al.* 1994).

Three main glaciations that covered Kodiak during the Pleistocene left behind discontinuous surficial deposits consisting of moraines, glacial till, and outwash. A small amount of alluvium occupies the short steep rivers of Kodiak. Volcanic ash from Aleutian Range eruptions forms a relatively continuous surficial layer throughout the Kodiak region (USFWS 1987).

2.3.3 Southcentral Region

Kenai Peninsula and Western PWS. Geologically, Kenai Peninsula is an extension of the same rock terranes found on Kodiak. Like Kodiak, the Chugach and Prince William terranes of Kenai and western PWS are accreted parts; that is, they were scraped off onto bending edges of the northern continental plate as the southern oceanic plate was underthrust (USFWS 1987). Most rocks of the Chugach and Prince William terranes of eastern Kenai Peninsula and the Chugach Mountains consist of metamorphosed, deep-water flysch deposits such as graywacke and slate; mafic volcanic and igneous rocks such as pillow basalts, greenstone, and gabbro; and ultramafic assemblages (e.g., McHugh Complex and Valdez group, Figure G-11) (Tysdal and Case 1979; Plafker *et al.* 1994; Siberling *et al.* 1994).

Aleutian-Alaska Range and Talkeetna Mountains. Geologically, the northern part of the Aleutian Range along the west side of Cook Inlet is an extension of the Alaska Peninsula. Jurassic intrusive rocks of the Aleutian-Alaska Range batholith form the backbone of the mountains in this area (Beikman 1980). A narrow band of Jurassic and Tertiary Peninsular terrane strata are juxtaposed against the intrusive rocks by the Bruin Bay fault (Figures G-8 and G-12). Quaternary volcanic rocks, including andesite flows and pyroclastic deposits, form the active stratovolcanoes of Augustine, Illiamna, Redoubt, and Mount Spurr (Alaska Volcano Observatory [AVO] 2004; Miller and Richter 1994).

Late Jurassic to Early Cretaceous strata of the Kahiltna assemblage overlies basement rocks of the Alaska Range and western Talkeetna Mountains in the northwest part of the southcentral region. These rocks consist of complexly deformed volcaniclastic turbidites, conglomerates, sandstone, graywacke, and phyllite deposited in slope and fan environments of a marine flysch basin, that later collapsed as a result of compressional tectonics (Nokleberg *et al.* 1994) (Figure G-12). Tertiary granitic rocks intrude these strata in the vicinity of Mount Spurr and on the south side of the Alaska Range (Figure G-8).

Peninsular and Kahiltna terrane rocks extend into the northeastern corner of the southcentral region, with Wrangellia terrane rocks sandwiched in between the two (Siberling *et al.* 1994). A major thrust fault, the Talkeetna thrust, places Wrangellia and Peninsular terrane rocks over the Kahiltna assemblage to the north. Together, these three terranes form the complexly deformed and metamorphosed Talkeetna Mountains. Within the planning region, Wrangellia terrane rocks consist primarily of Pennsylvanian and Permian marine volcanic rocks and shallow water limestone, and are interpreted to be the stratigraphic basement for Mesozoic Peninsular terrane rocks (Nokleberg *et al.* 1994). A large granite batholith of both Mesozoic and Tertiary age intrudes all three sedimentary terranes in this area, and flat-lying Tertiary basalt caps both the metasedimentary and plutonic rocks of the area (Beikman 1980; Selkregg 1974a) (Figure G-8).

Cook Inlet-Susitna Basin. Cook Inlet-Susitna Basin is an elongate, northeast-trending, fault-bounded basin that is bordered to the west and north by the Aleutian-Alaska Range and Talkeetna Mountains, and to the southeast by the Chugach and Kenai Mountains. The basin contains up to 25,000 ft of Tertiary strata overlying a 30,000-ft thick sequence of Mesozoic sedimentary rocks belonging to the Peninsular terrane (Selkregg 1974a; Swenson 1997). Together these deposits form important oil and gas, coal, and CBNG resources in the Ring of Fire planning area.

Stratigraphic columns for the Cook Inlet-Susitna Basin are provided on Figure G-13. Volcaniclastic rocks of the Lower Jurassic Talkeetna Formation form the effective basement of the basin. The overlying Middle to Upper Jurassic Tuxedni Group and Chinitna Formation contain rich marine-shale source rocks for all of the oil and some natural gas in the region. Along with the Cretaceous Matanuska Formation, these rocks were deposited in coastal to deep marine environments, and unconformably underlie the mostly nonmarine petroleum-bearing Cenozoic rocks (Magoon 1994 and 1996a).

The Cenozoic strata of Cook Inlet Basin overlap the Alaska Range batholith to the northwest and the Border Ranges Fault to the southeast (Beikman 1980; Magoon 1994) (Figure G-8). Primary stratigraphic units within the Tertiary section beneath Cook Inlet and Kenai Peninsula include the West Foreland, Hemlock, Tyonek, Beluga, and Sterling Formations. These units were deposited in a terrestrial fore-arc basin setting, and each contains reservoir rocks for oil or gas somewhere in the basin (Figure G-13a). In addition, numerous coal deposits were laid down and preserved throughout the Tertiary section, providing the primary source of natural gas in the Cook Inlet basin. The coal-bearing Paleocene Chickaloon Formation lies at the base of the Tertiary section in the Matanuska Valley area, but is absent beneath Cook Inlet and Kenai Peninsula (Figure G-13b) (Barnes and Payne 1956; Barnes 1962; Wahraftig *et al.* 1994). The Tyonek, Beluga, and Sterling Formations contain large coal deposits elsewhere in the basin, forming the Beluga, Kenai, Susitna, and Yentna coal fields (Merritt and Hawley 1986).

Surficial Deposits. Unconsolidated surficial deposits of the southcentral region consist chiefly of glaciofluvial sediments related to a succession of repeated Pleistocene glaciations, and the development of drainage systems from several large mountain ranges (Reger and Pinney 1997; Selkregg 1974a). As glaciers advanced and retreated, they left behind a complex series of deposits produced by the interplay between glacial ice, flowing streams, lakes, and estuaries. Moraines, till, and fine-grained glaciolacustrine deposits are common throughout the Kenai Peninsula, the Anchorage Bowl, and Susitna Valley. Fluvial deposits consisting of modified glacial outwash, alluvial fans, and floodplain and terrace deposits are present throughout the river systems of the southcentral region. Wind-blown silt and sand deposits occur in the Susitna delta area. Coastal beaches and spit deposits are common around Cook Inlet, particularly on the west side of Upper Cook Inlet (Selkregg 1974a).

2.3.4 Southeast Region

As described in Section 2.2.4, the rocks of the southeast region were emplaced during a series of subductions and accretions by colliding tectonic plates during Jurassic to early Tertiary time (Gehrels and Berg 1992 and 1994). Thus, the current geologic configuration of the area consists of a series of linear, northwest-trending terranes or lithic assemblages, each with a unique provenance and history prior to accretion. Stratigraphic columns for the rock terranes of the southeast region are depicted on Figures G-11 and G-14, and described below from northwest to southeast.

Yakutat, Chugach, and Wrangellia Terranes. Together these three terranes form the northwest margin of the southeast region from Yakutat Bay to the southern tip of Baranof Island. Yakutat Terrane rocks lie on the west side of the Boundary-Fairweather Fault from Yakutat Bay to the Lituya Bay area (Figure G-9), and extend northwest out of the Ring of Fire planning area towards PWS. Yakutat terrane rocks in the Ring of Fire planning area include the Jurassic- to Cretaceous-age Yakutat Group, composed of highly deformed marine sedimentary and volcanic rocks deposited in a submarine fan environment, which is overlain by mostly nonmarine Tertiary formations that thicken rapidly to the west (Gehrels and Berg 1994). Sandstones within the Tertiary formations have been the focus of oil and gas exploration in this area (Bruns 1996) (Section 3.1.1.1). From oldest to youngest, the Tertiary sequence includes siltstone and sandstone of the Stillwater Formation, coal-bearing terrestrial deposits of the Kulthieth Formation, deltaic and shallow marine deposits of the Tokun Formation, organic-rich marine shales of the Poul Creek Formation, and siltstone and sandstone of the Yakataga Formation (Figure G-11).

Chugach terrane rocks lie east of the Fairweather Fault, and extend from the head of Yakutat Bay south to the south end of Baranof Island. Chugach terrane rocks were emplaced during the Cretaceous as a result of plate convergence along the older Alexander and Wrangellia terranes, and are part of the same sequence of rocks that arc northwest towards Kenai Peninsula and the Kodiak region (Sections 2.3.2 and 2.3.3). These rocks consist of strongly deformed Mesozoic graywacke and slate, as well as a mélange of basalt, ultramafic, plutonic rocks, and argillite. Greenschist metamorphism overprints the inboard (eastern) side of these rocks (Gehrels and Berg 1994). Cretaceous to Tertiary-age granitic rocks intrude the older sequence and are exposed at the surface in isolated patches (Figure G-9).

Wrangellia Terrane contains the oldest rocks of the three terranes in this group, and is exposed on the east side of the Chugach terrane on northwest Chichagof Island. This block is interpreted to be an extension of the Wrangellia Terrane that arcs towards Interior Alaska and into the Talkeetna Mountains (Siberling *et al.* 1994) (Section 2.3.3). On Chichagof, these rocks consist of Mesozoic basalt, limestone, and deep-marine sedimentary rocks, overlying upper Paleozoic metavolcanics, metasedimentary rocks, and marble (Gehrels and Berg 1994).

Alexander Terrane and Gravinia Belt. The Alexander terrane occupies the largest area of the southeast region, and contains some of the oldest rocks in Alaska. It comprises a variety of sedimentary, metamorphic, and plutonic rocks of Late Precambrian to Middle Jurassic age. Alexander terrane rocks are found in the Glacier Bay area, on the west side of Lynn Canal and Chatham Strait, and on the northeast half of Chichagof Island. They also cover most of Admiralty and Kuiu Islands, lie within central sections of Kupreanof and Zarambo Islands, and are exposed throughout Prince of Wales Island and adjacent smaller islands to the west (Figure G-9).

Much of the Alexander Terrane formed near a paleoequator in an oceanic and volcanic island arc environment, prior to northward rafting that resulted in the current structural setting. Precambrian volcanogenic greenschist and marble are located in the southwest corner of the terrane. Lower to middle Paleozoic strata (Ordovician, Silurian, Devonian ages) are the most widespread geologic units within the Alexander Terrane, and consist of turbidites, shallow marine carbonates, and conglomerate (Gehrels and Berg 1994; Beikman 1980). Upper Paleozoic rock units consist primarily of shallow marine carbonates and clastic sedimentary rocks, as well as mafic to intermediate volcanic rocks. Mesozoic strata overlie the older rocks on a regional unconformity, and include basal conglomerate, tuff, limestone, argillite, and pillow basalts that may have formed in a rift environment (Gehrels and Berg 1994). Cretaceous granitic intrusive rocks on southern Prince of Wales Island formed as the youngest component of the Alexander Terrane prior to accretion.

Gravinia Belt rocks occur in narrow strips along the southeast side of the Alexander Terrane along the eastern coasts of Admiralty and Kupreanof Islands. These rocks consist of Jurassic to Cretaceous marine slate and graywacke, and interbedded andesitic to basaltic volcanic rocks, with lesser amounts of conglomerate and intrusives (Beikman 1980; Gehrels and Berg 1994). These rocks record a transition in metamorphism from low grade on the west to higher grade on the flanks of the Coast Mountains to the east.

Taku Terrane and Coast Mountains Batholith. Taku terrane rocks lie along the east side of the Alexander and Gravinia rocks, and consist mostly of poorly understood Paleozoic and Mesozoic rocks characterized by strong deformation and high-grade metamorphism. Recognizable rock types within the sequence are similar to Gravinia Belt rocks, and include basalt, fine-grained marine sedimentary rocks, tuffs, carbonates, and metaconglomerates (Gehrels and Berg 1994; Siberling *et al.* 1994).

The Coast Mountains Batholith consists mostly of Cretaceous to Tertiary plutonic rocks of intermediate to felsic composition (Beikman 1980) (Figure G-9). These rocks were intruded during the later stages of regional metamorphism and deformation of adjacent terranes beginning in the Cretaceous, and become progressively younger (Eocene-aged) towards the east and south (Moll-Stalcup *et al.* 1994). These rocks are interpreted to have originated in Andean-type continental margin arc in response to subduction, or as partial melting of older metamorphic rocks during regional metamorphism (Gehrels and Berg 1994).

Surficial Deposits. Unconsolidated deposits cover most of the lowlands of the southeast region, but are thin or absent in the uplands. Much of the surficial material is of glacial origin deposited during multiple Pleistocene advances. Glacial retreats left behind deposits of moraines, outwash plains, a ubiquitous thin veneer of compact till, glaciofluvial material, and fine-grained glaciolacustrine deposits at the heads of ice-dammed valleys. Stream deposits of silt, sand, and gravel are common along most streams (Selkregg 1974c). Beach gravel deposits occur along many shorelines. A narrow coastal plain characterized by glacial outwash and longitudinal beach ridges lies along the coast in the Yakutat area (Nowacki *et al.* 2002; Wahrhaftig 1965).

2.4 Geophysics/Geochemistry

The following discussion provides an overview of geophysical and geochemical data available for the Ring of Fire planning area that are typically used in the identification and interpretation of mineral resources.

2.4.1 Geophysical Data

Aeromagnetic Surveys. The presence of magnetic minerals in rocks causes distortions or anomalies in the earth's magnetic field that, when interpreted alongside geologic data, can provide evidence of mineralized areas. Predictive models are developed from aeromagnetic data for specific geologic units, and, in combination with geochemical analyses of stream sediment, can be extrapolated to improve upon existing geologic maps and predict mineral potential.

Aeromagnetic data collected in the Ring of Fire planning area from the 1960s through the 1980s were first compiled into a regional contour map by Godson (1984 and 1991). More recently, digital magnetic surveys have been completed by the Alaska Division of Geological & Geophysical Surveys (DGGS), BLM, U.S. Geological Survey (USGS), and contracted scientists for targeted areas of Alaska, in an effort to provide additional tools for exploration of new mineral resources (DGGS 2004; Saltus and Simmons 1997; Saltus *et al.* 1999a). Electromagnetic and apparent resistivity data were also derived from these surveys.

Within the southcentral region, digital aeromagnetic surveys have been completed for the Tyonek, Anchorage, Petersville, and Talkeetna areas (Alstatt *et al.* 2002; DGGS 2004; USGS 2002). Surveys have been completed for the Stikine and Ketchikan mining districts, within the southeast region (DGGS 2004; Still *et al.* 2002; Wynn *et al.* 2001). The results of recent surveys conducted in the Stikine area, for example, have shown promising correlations between magnetic signatures and volcanic massive sulfide (VMS) mineral occurrences (Still *et al.* 2002; Wynn *et al.* 2001). A number of additional mineral terranes within the Ring of Fire planning area being considered for future aeromagnetic surveys depending on state funding levels. These include the west side of lower Cook Inlet near Lake Illiamna; the Yentna, Skentna, Willow Creek, King Mountain, and Yenlo Hills areas of the southcentral region; and Chichagof Island, southeast Prince of Wales Island, and the Haines/Klukwan area of the southeast region (DGGS 2004; Burns 2004).

Gravity Data. Isostatic gravity data was collected for portions of the Ring of Fire planning area in the 1970s and 1980s. These surveys were compiled in a comprehensive map by Barnes *et al.* (1994). Gravity data are sensitive to lateral rock density variations in the earth's upper crust. In the Ring of Fire planning area, gravity data depict major lows caused by low-density sediments in the upper Cook Inlet-Susitna basin as well as the coastal Yakutat area. Arcuate highs exist along the Alaska Peninsula, western PWS, the Chugach and Talkeetna Mountains, and in the northwestern corner of the southeast region, which probably reflect the presence of mafic and ultramafic rocks in these regions (Barnes *et al.* 1994; Patton *et al.* 1994; Saltus *et al.* 1999a; Saltus *et al.* 1999b).

Aeroradiometric Data. Airborne gamma-ray spectrometry surveys were conducted in some regions of the Ring of Fire planning area between 1975 and 1980 as part of the National Uranium Resource Evaluation (NURE) program. This program was initiated by the U.S. Atomic Energy Commission in the 1970s with the primary goal of identifying uranium resources in the U.S. (Smith 1997). Gamma-ray surveys measure radioactive decay of the naturally occurring elements potassium, uranium, and thorium. In addition to directly sensing these elements, radiometric data can be used to locate intrusive rocks or map rock units with distinctive radiometric signatures, such as metamorphic rocks with uranium-bearing minerals. Thus, the data can be used to differentiate different types of rocks and soils, and to aid in mineral exploration (Duval 2001; Saltus *et al.* 1999b). Within the Ring of Fire planning area, radiometric surveys have been completed for the northwest corner of the Alaska Peninsula, most of the southcentral region, and all of the southeast region.

Seismic Reflection and Electric Log Data. Geophysical data such as seismic reflection data and downhole logging methods are commonly used in the oil and gas industry to identify exploration prospects and maximize well production. Seismic data related to oil and gas exploration are largely company-confidential and were not reviewed for this analysis. Electric logs for wells in developed fields and older exploration wells are typically available at the Alaska Oil and Gas Conservation Commission (AOGCC) and the Alaska Department of Natural Resources (ADNR) Division of Oil & Gas (2004c).

Geophysical Methods in Geothermal Exploration. Self-potential (S-P) resistivity surveys and refraction seismic methods were used to conduct geothermal exploration and siting investigations in the Aleutians in the 1980s (e.g., DGGS 1986; Motyka *et al.* 1985; Republic Geothermal, Inc. 1985). S-P anomalies from fluxes of water and heat through the subsurface can generate measurable natural electrical fields or S-Ps (Hoover *et al.* 1995). In the Aleutians, S-P surveys have been used to identify the location of reservoirs containing superheated saline groundwater adjacent to volcanoes. Seismic refraction data have been used in conjunction with borehole stratigraphy to identify cross-hole structural and stratigraphic changes (DGGS 1986).

2.4.2 Geochemical Data

Petrologic and Elemental Data. Numerous studies are available documenting the petrology and chemical composition of various rock types in southern Alaska. Moll-Stalcup *et al.* (1994) provide a summary of petrologic and chemical data for the volcanic and intrusive rocks of southern Alaska. Various researchers have conducted geochemical analyses of specific regions; for example, Kay and Kay (1994) provide representative analyses of Aleutian andesitic magmas. Dusel-Bacon (1994) gives a comprehensive interpretation of the metamorphic facies composition for all of Alaska. Barker *et al.* (1994), and Miller and Richter (1994) summarize elemental concentrations of some of the Quaternary and older accreted volcanic rocks within the Ring of Fire planning area. Nokleberg *et al.* (1987 and 1994) summarize metalliferous concentrations of significant lode and placer deposits in Alaska from geochemical analyses. Geochemical analyses have also been compiled for rocks of specific mining districts in southern Alaska by the former U.S. Bureau of Mines (USBOM) and BLM (e.g., Bittenbender *et al.* 1999; Jansons *et al.* 1984; Maas *et al.* 1995; Still *et al.* 2002).

Several online databases provide the results of elemental geochemical analyses from stream sediment samples within the Ring of Fire planning area. An extensive Hydrogeochemical and Stream Sediment Reconnaissance program was conducted as part of NURE (Section 2.4.1), resulting in the collection of thousands of stream sediment, soils, lake sediment, and well water samples across Alaska and the contiguous U.S. These data include elemental uranium concentrations, as well as a number of other elements (Grossman 1998; USGS 2004c), and are available on a quadrangle basis for selected areas of the Ring of Fire planning area (e.g., Wiltse 1991a and 1991b). Similarly, the USGS' Rock Analysis Storage System (RASS) provides elemental geochemical data from stream sediments, soils, waters, and organic material that can be downloaded on a quadrangle basis. RASS is intended as a reconnaissance tool for identifying the regional geochemical signature of an area for mineral exploration or environmental baseline purposes (Bailey 2004). Stream sediments were chosen as the principle sample medium for these programs because they integrate many rock sources within a drainage basin and allow for lower sample density. Approximately 28,000 sample results are available from RASS for the Ring of Fire planning area (Bailey *et al.* 2000 and 2004). Additional stream sediment samples have been collected by BLM as part of specific mineral assessment studies in the Ring of Fire planning area (e.g., Bittenbender *et al.* 2001; Maas *et al.* 1995).

The USGS conducted a multidisciplinary resource assessment program in the early 1970s through early 1990s that included geologic mapping, geochemical sampling, and airborne geophysics (Bailey 2004). These efforts, called the Alaska Mineral Resource Appraisal Program (AMRAP) were synthesized on a quadrangle basis for selected areas of Alaska (e.g., Liss and Wiltse 1993a and 1993b). PLUTO is a USGS database that provides the results of geochemical analyses on plutonic and volcanic igneous rock samples. Approximately 2,800 samples are available on PLUTO database for the Ring of Fire planning area, including samples from the Aleutians, Alaska Peninsula, Kodiak, Kenai Peninsula, Susitna Basin, and the southeast region (USGS 2004c).

Petroleum Geochemistry. The geochemistry of petroleum systems in Cook Inlet has been summarized by Magoon (1994). These data include oil gravity, sulfur content, pristane/phytane ratios, carbon isotope values, gas specific gravity, percent methane, and gas heating values for each field and stratigraphic/production unit. Selected geochemical data, as well as information related to reservoir characteristics and production, are provided in Table G-2 for the onshore oil and gas fields within the Cook Inlet Basin. Chemical markers from the Cook Inlet oil fields indicate that the oil originates from marine-shale source rock. Chemical data for Cook Inlet natural gas provide an indication of its origin as part biogenic and part thermal (Magoon 1994).

Magoon (1994) also summarizes the petroleum geochemistry of the Gulf of Alaska Basin, the southeast corner of which extends into the southeast region of the Ring of Fire planning area. Geochemical analyses of potential source rocks across the basin suggest that, while source rocks are mature enough to generate oil in the Katalla Field to the northwest near Cordova, they decrease in thermal maturity to the southeast. Oils in the southeast portion of the basin generally have lower gravities (13^{o} to 37^{o} American Petroleum Institute), higher sulfur contents, and are lacking in normal alkanes compared to oils in the northwest part of the basin, indicating that they may be biodegraded.

Molenaar (1996a; 1996b) describes general geochemical characteristics of speculative Mesozoic and Tertiary oil and gas plays on the Alaska Peninsula. In general, the thermal maturity of source rocks on the northwest side of the peninsula (Tertiary play area) is expected to be less than that of the southeast side of the peninsula (Mesozoic play area).

Coal Geochemistry. Merritt and Hawley (1986) summarize the geochemistry of coalfields and coal districts of Alaska. The classification of coal by rank is generally a measure of the metamorphism it has undergone since burial. Coal ranks are divided into four classes: in decreasing order of carbon content and heat value, these are anthracite, bituminous coal, subbituminous coal, and lignite (American Society of Testing and Materials [ASTM] 1999; Wahrhaftig *et al.* 1994; Wood *et al.* 2003). Within the bituminous class, coals are further subdivided into five groups based on the amount of volatile matter present and heat value (low volatile, medium volatile, and high volatile A, B, and C) (U.S. Department of Energy [USDOE] 2004b; Wood *et al.* 2003).

Within the Ring of Fire planning area, high rank anthracite coals are known to occur only in the northeast portion of the Matanuska Field, changing to bituminous coal towards the southwest. Overall, Matanuska Field coals have heating values in the range of 10,000 to 14,000 British thermal units per pound (Btu/lb). Merritt and Hawley (1986) and DGGS (1993a) list the geochemical characteristics of Matanuska coals, including percent carbon, volatiles, sulfur, and ash content; the major oxides and trace element composition of the ash; vitrinite reflectance; and a breakdown of organic constituents (maceral composition). Other coal fields of the Cook Inlet-Susitna basin (Beluga, Kenai, Susitna, and Yentna Fields) contain lower rank subbituminous coals, with heating values in the range of 5,400 to 9,500 Btu/lb (Merritt and Hawley 1986).

On the Alaska Peninsula, the Chignik Field and Ugashik District contain high-rank bituminous coals, while those of the Herendeen Bay Field are partly bituminous on the northwest side of the field, changing to lignite to the southeast. The coal district on Unga Island is composed of low-rank lignite. A complete geochemical breakdown of the Chignik and Herendeen Fields is provided by DGGS (1993a).

In the southeast region, the Admiralty and Angoon coal districts located on Admiralty Island are considered bituminous. Several small outcroppings that comprise the Kuiu District on Kuiu Island contain lignite (Merritt and Hawley 1986).

CBNG Geochemistry. CBNG is a methane-rich natural gas that is generated during the conversion of plant material to coal, and is stored in the micropores of coal layers. CBNG is mainly composed of methane, with small quantities of other hydrocarbons such as ethane and propane. It typically contains few impurities, such as hydrogen sulfide and carbon dioxide normally found in natural gas. CBNG is comparable in heating value to conventional natural gas (about 1,000 Btu/standard cubic ft [scf]) (Clough 2001).

The presence and productivity of CBNG is dependent on thermal maturity and other non-geochemical factors (Section 3.1.3.1). High volatile B bituminous coals with vitrinite reflectance (Ro) between 0.6 and 1.0 percent are the minimum threshold of thermal maturity required for the generation of significant amounts of thermogenic gas (Dolan 2002; Tyler *et al.* 2000).

Geochemical analyses of CBNG from a test well in the Cook Inlet-Susitna basin of the southcentral region are summarized by Smith (1995). Coal seams sampled for CBNG between depths of approximately 500 to 1,200 ft indicate gas contents in the range of 63 to 245 scf/ton, vitrinite reflectances increasing with depth up to a maximum of 0.58 percent, and low moisture contents in the range of 4.82 to 9.02 percent. Gas composition was 98 percent methane with minor amounts of carbon dioxide and nitrogen. Carbon isotope analyses indicated that CBNG has both thermogenic and biogenic sources in this area, and that the ratio of thermogenic to biogenic gas increases with depth.

Although CBNG geochemical data are not available for the Alaska Peninsula, Molenaar (1996) indicates that the thermal maturity of conventional oil and gas source rocks on the northwest side of the peninsula is generally less than that of the southeast side of the peninsula, and that the northwest side may be favorable for biogenic gas. Tyler *et al.* (2000) summarize coal geochemical data relevant to CBNG from the Chignik coal field on the southwest side of the peninsula. Vitrinite reflectance values of surface coals (averages of 0.64 to 0.76 percent) indicate that most of the subsurface coals in the area have probably reached, or are approaching, the threshold required for thermogenic methane generation. Maceral composition analyses of coals from the Chignik, Herendeen Bay, and Unga Island fields on the southeast side of the peninsula suggest that the coals generally have good gas-generating potential.

Geochemical data for thermal springs within the Ring of Fire planning area have been summarized in a number of DGGS publications (e.g., Motyka *et al.* 1983 and 1993; Motyka and Moorman 1987). Measurements of temperature, pH, and total dissolved solids are provided for numerous fumeroles and hot springs in the Aleutians and Alaska Peninsula, for summit fumeroles in the four large volcanoes along the west side of Cook Inlet, for an exploratory well in the Susitna basin, and for about 20 hot springs in the southeast region. These publications also describe the use of chemical geothermometry data to estimate subsurface reservoir temperature (Section 3.1.4.1).

3.0 DESCRIPTION OF MINERAL RESOURCES AND OCCURRENCE POTENTIAL

As indicated in Section 1.2, mineral resources on BLM-managed surface and subsurface lands are divided into leasable, locatable, and salable categories based on provisions of various mining laws. The following discussion of known and potential resources within the Ring of Fire planning area is broken down into three sections according to these categories.

3.1 Leasable Minerals

Leasable minerals present in the Ring of Fire planning area include oil and gas, coal, CBNG, geothermal resources, and certain solid minerals. The known resources and occurrence potential of each leasable mineral type are discussed in Sections 3.1.1 through 3.1.5.

3.1.1 Oil and Gas

3.1.1.1 Basins, Fields, Plays, and Production History

Known sedimentary basins with oil and gas potential are located within the Ring of Fire planning area in the following areas: the Alaska Peninsula, the Cook Inlet-Susitna Basin in the southcentral region, and the western edge of the Copper River Basin, and the Yakutat area of the southeast region (Ehm 1983; Kirschner 1992; Magoon *et al.* 1996). Figures G-15 through G-18 depict the location of sedimentary basins mapped by Ehm (1983), exploration wells from ADNR Division of Oil and Gas (2004e), existing state and federal leases (ADNR Division of Oil and Gas 2004b), federal and state unit boundaries for existing fields (ADNR Division of Oil and Gas 2004b), USGS oil and gas assessment play areas (USGS 1995; Beeman *et al.* 1996), and occurrence potential (described in Section 3.1.1.2). These data, as well as the production history of existing oil and gas fields in the planning area, are summarized below by geographic region.

The USGS conducts estimates of conventional oil and gas resources in the U.S. based on the concept of a “play,” which is defined as a set of discovered or undiscovered oil and/or gas accumulations sharing similar geographic boundaries and geologic attributes, such as source rock, reservoir type, and trap. Periodic National Assessments have been conducted by USGS since the early 1900s, in which known or postulated plays were refined in each successive study based on new data and techniques. Joint assessments by USGS for onshore resources and by Minerals Management Service (MMS) for offshore resources have been conducted since the 1980s. The most recent National Assessment was conducted in 1995 (USGS 1995; MMS 1996).

BLM (1990) guidance directs that the evaluation of fluid mineral potential on BLM-managed lands be based on USGS resource estimates. Thus, the evaluation of oil and gas resources in the following paragraphs is derived largely from 1995 USGS play analyses and reserves modeling (USGS 1995; Beeman *et al.* 1996; Gautier *et al.* 1996).

Alaska Peninsula/Aleutian Chain Region

The Aleutian Chain is generally considered to have no onshore oil and gas potential (USFWS 1988). Additionally, MMS (1996) describes the oil and gas potential of offshore sedimentary basins adjacent to the islands as negligible. Sedimentary basins of the Bering Shelf region at the east end of the Aleutian Chain (St. George Basin and North Aleutian Basin) are considered to have the potential for oil and gas in Tertiary deposits. Exploration wells drilled in the 1980s in St. George Basin northwest of Unimak Island (Figure G-15) did not encounter significant shows of oil or gas (MMS 1996).

On the Alaska Peninsula, two groups of sedimentary rocks have been designated as play areas for potential oil and gas reserves by USGS (Molenaar 1996a): 1) Mesozoic sedimentary rocks extending along the southeast part of the peninsula, and 2) Tertiary strata of the North Aleutian or Bristol Bay Basin, which extends along the northwest coast of the peninsula (Figure G-7). The stratigraphy of each group is introduced in Section 2.3.1 and depicted on Figure G-10.

To help improve the local economy and alleviate escalating energy costs in the Bristol Bay region, there is renewed interest in oil and gas leasing. The State is planning to offer oil and gas leases in the area in October 2005, including onshore acreage along the north half of the peninsula underlain by both Tertiary and Mesozoic plays (ADNR Division of Oil and Gas 2004a; Anchorage Daily News [ADN] 2004b).

Mesozoic Play. This has been described by the USGS (Molenaar 1996a and 1996b) as a hypothetical structural play for Mesozoic oil accumulations under large anticlines of the Alaska Peninsula. Mesozoic rocks outcrop along the southeast side of the peninsula and underlie part of the Bristol Bay Basin to the north. From the Cold Bay area to Port Heiden, the play area encompasses both sides the peninsula; at Port Heiden, the western edge of the play trends towards the center of the peninsula along the projected Bruin Bay Fault (Figure G-15).

Mesozoic strata on the Alaska Peninsula include Late Triassic limestone and shale of the Kamishak Formation; and a number of graywacke, sandstone, and shale formations of Jurassic and Upper Cretaceous age. The primary reservoir rock is a reefoid and biostromal limestone of the Kamishak Formation. The Jurassic and Cretaceous graywackes and dirty sandstones are considered to have poor reservoir potential. Good source rocks have been identified in marine mudstones in Upper Triassic and possibly Middle Jurassic strata, and large oil seeps have been documented along the peninsula. Exploration wells have encountered more mature Triassic source rocks at depth than in outcrops (Molenaar 1996a and 1996b).

Of 26 exploration wells drilled on the Alaska Peninsula between 1903 and 1983, 18 were for Mesozoic prospects on large structures that were all unsuccessful (Molenaar 1996a and 1996b). The earliest shallow wells, drilled on anticlines southeast of Becharof Lake, did not reach Triassic strata. At least three wells on the peninsula penetrated Triassic strata, but none encountered biostromal facies considered to have the best reservoir potential. Drilling depths for Triassic rocks are in the range of 12,000 to 20,000 ft.

The USGS considers the Alaska Peninsula Mesozoic play to be very speculative, limited mostly by the lack of good reservoir rock. The USGS rates oil and gas plays based on the probability of occurrence of three attributes: source, reservoir, and trap. The Mesozoic play has individual ratings of 0.9 for source rock, 0.3 for reservoir rock, and 0.9 for structural traps; with a combined probability of occurrence of 0.24 (or 24 percent). The USGS' estimate of undiscovered resources for this play averages 52.1 million barrels of oil (MMBO), based on modeled estimations of the size and number of undiscovered accumulations, gas-to-oil ratios, oil gravity, and depth.

Tertiary Play. The USGS describes this as a hypothetical play for both oil and gas in Tertiary shallow marine and nonmarine sandstone occurring in broad open folds that underlie alluvium of the Bristol Bay lowlands. The play area extends along the northwest side of the peninsula from about Cold Bay to the Egegik and Becharof Lake area (Figure G-15).

Tertiary strata of the Alaska Peninsula include mudstone, siltstone, sandstone, volcanics, coal, and conglomerate of the Tolstoi, Belkoski, Stepovak, Meshik, Bear Lake, and Tachilni Formations (Section 2.3.1, Figure G-10). Potential reservoir rocks include sandstone beds ranging from 50 to 100 ft thick that occur throughout the Tertiary sequence, as well as Oligocene volcaniclastic rocks in the Port Heiden area. Source rocks include nonmarine coaly and carbonaceous strata within the Tertiary sequence, and possibly Mesozoic source rocks underlying the southwestern part of the play area. The nonmarine origin of most source rocks in the area suggests that this is dominantly a gas play (Molenaar 1996a and 1996b).

Between 1959 and 1983, nine exploration wells were drilled on the peninsula for Tertiary prospects to depths of 8,000 to 15,000 ft. None were considered successful, although gas shows and slight oil shows were encountered. The sandstone reservoirs were generally of poor quality. The abundance of coal encountered, and low thermal maturity of the hydrocarbons, suggest that the area may be favorable for biogenic gas or CBNG (Section 3.1.3). The USGS gives the Alaska Peninsula Tertiary play a combined probability of occurrence of 0.32, based on individual probabilities of 0.5 for source rock, 0.8 for reservoir rock, and 0.8 for structural traps. Their estimates of undiscovered resources for this play average 1.3 MMBO for oil and 5.0 MMBO equivalent for natural gas (Molenaar 1996b).

Kodiak Region

The onshore portion of the Kodiak region is considered to have little geologic potential for oil and gas. Known sedimentary basins containing Tertiary rocks are located offshore to the northwest (Shelikof Basin), southwest (Tugidak Basin), and southeast (Kodiak shelf area). Some oil and gas leasing activities and exploration has been conducted on the Kodiak shelf and in Shelikof Strait, which is a southern extension of Cook Inlet Basin. Tertiary sedimentary rocks of the Kodiak Shelf outcrop in a narrow band along the southeast coast of Kodiak Island and on Tugidak and Trinity Islands, but the play area for oil and gas in this basin is primarily offshore to the east. The remainder of sedimentary rock types on Kodiak is Mesozoic, which are considered to have little to no petroleum potential in this area (USFWS 1987; Fisher 1996).

Southcentral Region

Cook Inlet Basin of the southcentral region is a known oil and gas province with about 15 currently producing oil and gas fields. These onshore fields are located near the inlet; the closest fields are approximately 15 miles east of BLM’s unencumbered lands in the Neacola Mountains and approximately 50 miles west of the Knik River block of selected lands. Production and reservoir characteristics of existing onshore fields in the basin are provided in Table G-2. Exploration wells, active federal and state leases, and unitized fields are shown on Figures G-16 and G-17 for both the onshore and offshore parts of Cook Inlet Basin, although the Ring of Fire planning area comprises only the onshore part of the basin. The leases shown on the figures are conventional oil and gas leases, while the wells and fields/units include those for both conventional oil and gas, as well as for shallow gas, because the ADNR Division of Oil and Gas handles permitting functions for both resource categories. State shallow gas leases, for which CBNG is usually the target, are shown on Figure G-20, and CBNG is discussed separately in Section 3.1.3.

Exploration activities in Cook Inlet began in 1902, and the first field, Swanson River oil field, was discovered in 1957. Following its discovery, seven oil and 23 gas accumulations were discovered over the next 15 years, with drilling activity peaking in the late 1960s (Magoon 1994). Onshore oil and gas fields are listed in Table G-2 in order of discovery date. Recent onshore exploration has taken place in the Ninilchik and Deep Creek areas of Kenai Peninsula (Figure G-16, Table G-2), and in the Pretty Creek and Kustatan (Redoubt) areas on the west side of Cook Inlet (Figure G-17) (ADNR Division of Oil and Gas 2002, 2003a, and 2003c; Petroleum News 2003).

The stratigraphy of the Cook Inlet–Susitna Basin is introduced in Section 2.3.3 and depicted on Figure G-13. The USGS recognizes three different oil and gas plays in the basin based on reservoir age and petroleum type. From youngest to oldest, these are: 1) the Beluga-Sterling gas play, 2) the Hemlock-Tyonek oil play, and 3) the Late Mesozoic oil play. The boundaries of these three play areas are depicted on Figures G-16 and G-17, and their attributes are described in the following paragraphs.

Beluga-Sterling Gas Play, Cook Inlet-Susitna Basin. This is a play for additional gas accumulations in late Tertiary sandstone reservoir rocks of the Cook Inlet and Susitna basins. Discovered reserves in this play (both onshore and offshore) total 6.14 trillion cubic ft of gas (TCFG). Most of the onshore petroleum resources within the Ring of Fire planning area fall into this play category. The largest onshore fields in this play are the Kenai and Beluga gas fields (e.g., Brimberry *et al.* 1997). Many of the known gas fields are undeveloped because they are too small or too expensive to produce (Magoon 1996a and 1996b).

Most of the gas in this play is produced from the Pliocene Sterling Formation, followed by the Upper Miocene Beluga Formation and Oligocene-Miocene Tyonek Formation (Figure G-13). Siliclastic, slightly conglomeratic sandstones of the Sterling Formation are the most important reservoir rocks in this play. Individual sandstone layers range from 24 to 600 ft in thickness. The source of the gas is unclear, although chemical data indicate that it is part microbial and part thermal. Coals and kerogen in the Beluga Formation beneath the Sterling are in a good position to charge the overlying reservoirs with microbial gas. The traps for these accumulations are mostly structural, with some combined structural and stratigraphic traps related to siltstone seals (Magoon 1994 and 1996a). The structural traps are complex, discontinuous anticlines that developed through right-lateral and compressional forces related to subduction zone tectonics. Many of the gas field folds and faults are still actively deforming (Haeussler *et al.* 2000).

The USGS gives the Beluga-Sterling gas play a probability of occurrence of 1.0 because it is a confirmed play. Their estimate of undiscovered resources for this play average 13.9 MMBO gas equivalent or 738 billion cubic ft of gas (Magoon 1996b). A state lease sale in May 2004 in upper Cook Inlet indicated a high level of industry interest in onshore tracts that are likely targeting conventional gas and/or CBNG accumulations on the Kenai Peninsula in the Soldotna and Anchor Point areas, as well as on the west side of Cook Inlet from the MacArthur River (Trading Bay) to Big Lake (ADN 2004d) (Section 3.1.3.2).

Hemlock-Tyonek Oil Play, Cook Inlet Basin. The extent of the Hemlock-Tyonek oil play is similar to that of the Beluga-Sterling gas play, except that the oil play does not extend into the Susitna Basin north of the Castle Mountain Fault (Figure G-17). Most of the confirmed oil fields in this play are located in offshore Cook Inlet outside of the Ring of Fire planning area. The two onshore fields are located on the northern Kenai Peninsula: the Swanson River and Beaver Creek oil fields, with total production and reserves of about 230 MMBO and 5 MMBO, respectively (Magoon 1994 and 1996a). Production depths in these fields are on the order of 10,000 to 15,000 ft.

Most of the oil in this play (about 80 percent) comes from the Oligocene Hemlock Conglomerate, which is primarily a conglomeratic sandstone; with the remainder coming from overlying and underlying sandstones of the Tyonek and West Foreland Formations (Figure G-13). Reservoir thicknesses range from 100 to 1,300 ft. The source of the oil is the Upper Jurassic Chinitna Formation in upper Cook Inlet, and Upper Triassic - Middle Jurassic rocks in lower Cook Inlet (Magoon 1994, 1996a and 1996b). The USGS gives the Hemlock-Tyonek oil play a probability of occurrence of 1.0, and provides an average estimate of undiscovered reserves of 647 MMBO (Magoon 1996b).

Late Mesozoic Oil Play, Cook Inlet Basin. The USGS describes this as a hypothetical play for oil accumulations in Mesozoic structural traps that unconformably underlie the Tertiary sequence. Oil has previously been recovered from Mesozoic strata in several wells in offshore lower Cook Inlet, and in the Swanson River oil field on northern Kenai Peninsula (Magoon 1996a). The play area is similar to that of the Hemlock-Tyonek play, except that the Late Mesozoic play extends southwesterly along the west side of lower Cook Inlet to connect with the Mesozoic play of the Alaska Peninsula (Figure G-16).

Potential reservoir rocks in this play include Cretaceous and Jurassic-age sandstones and turbidites of the Matanuska, Kagayak, and Naknek Formations (Figure G-13). Potential traps include faulted anticlines, unconformities, and facies changes to siltstone. Reservoir rocks encountered in this sequence are mostly of poor quality. The source of the oil is the Upper Jurassic Chinitna Formation (Magoon 1994 and 1996a). The USGS gives the Mesozoic play a combined probability of occurrence of 0.09, based on individual probabilities of 1.0 for source rock, 0.3 for reservoir rock, and 0.3 for traps. The USGS has not conducted a quantitative estimate of reserves for this play (Magoon 1996b). In 2004, a federal lease sale in the offshore area adjacent to this play failed to draw any industry interest (ADN 2004a).

Copper River Basin. Potential oil and gas resources of the Copper River Basin are located mostly outside of the Ring of Fire planning area to the east. The USGS recognizes two oil and gas plays in the basin, one of which, a Mesozoic oil play, extends into the Ring of Fire planning area (Figure G-17). The reservoir rocks for the Mesozoic play are sandstones of the Matanuska Formation, and source rocks are possibly Jurassic shale, as is the case in Cook Inlet. Traps are structural, stratigraphic, or both. The overall probability for this play is considered to be low because evidence is lacking for traps or for sufficient oil to fill the traps. The USGS has not conducted a quantitative reserve estimate for this play (Magoon and Valin 1996).

Southeast Region

The eastern part of the Gulf of Alaska sedimentary basin extends into the Yakutat area of the southeast region (Figure G-18) (Ehm 1983; Kirschner 1992). The oil and gas potential of this and other areas of the southeast region, are discussed in the following paragraphs.

Yakutat Foreland/Lituya Play. The Gulf of Alaska sedimentary basin lies within the Yakutat tectonic terrane of the southeast region (Section 2.2.4). The basin is divided into three segments based on changes in basement rocks and Lower Tertiary strata thickness. The Dangerous River Zone, trending north-northwesterly through Yakutat Bay, represents the eastern margin and paleoslope of an older basin (MMS 1995). The Ring of Fire planning area lies mostly on the east side of this zone, in the easternmost segment of the Gulf of Alaska Basin. The stratigraphy of the Yakutat terrane is introduced in Section 2.3.4 and depicted on Figure G-11.

The Yakutat Foreland/Lituya play extends along the coastline from west of Yakutat Bay to about 15 miles southeast of Lituya Bay, and lies between the Boundary-Fairweather Fault system to the northeast and the offshore three-mile limit to the southwest (Figure G-18). The USGS describes this as a hypothetical play of oil and associated gas in relatively undeformed Cenozoic strata east of the Dangerous River Zone. The primary reservoir rocks are sandstones within the mostly nonmarine Late Tertiary formations of the Yakutat Terrane (Bruns 1996a). Equivalent plays in the adjacent offshore area include sandstones of the Kulthieth, Yakataga, and Poul Creek Formations (Figure G-11) as potential reservoir rocks (MMS 1995). The depth range of the Tertiary reservoirs in the onshore play is from 1,500 to 30,000 ft. The Tertiary strata dip steeply away from the Boundary-Fairweather Fault system and thicken rapidly seaward. Source rocks lie within Lower Tertiary strata west of Yakutat Bay, and hydrocarbons are speculated to have migrated updip towards the east and onshore area. Traps may include folds or faults associated with deformation near the Dangerous River Zone, or paleomargin-related stratigraphic traps such as updip pinch-outs or basement onlaps (Bruns 1996a and 1996b; Magoon 1994; MMS 1995).

The Yakutat onshore area was explored in the late 1950s through early 1960s. Eight wells were drilled on the coast southeast of Yakutat Bay to maximum depths of 12,000 ft. Only one of these had a show of oil and gas; the rest were dry (Selkregg 1974c). One well was drilled offshore of this area, but west of the Dangerous River Zone; it had oil shows but produced no hydrocarbons (MMS 1995). The USGS suggests that further exploration in the onshore play may be warranted if subtle structural or stratigraphic traps could be identified on seismic data, or if significant offshore accumulations were found. They give the Yakutat Foreland play a combined probability of occurrence of 0.4, based on individual probabilities of 0.8 for source rock, 1.0 for reservoir rock, and 0.5 for traps. They provide an average estimate of undiscovered reserves of 57 MMBO (Bruns 1996b).

Central and Southern Southeast Region. There have been reported indications of unconfirmed oil seeps in the Keku Islands southwest of Kake, and in the Heceta Island area south of Edna Bay (Figure G-18). Possible source rocks in these areas are Silurian or younger limestones that are reported to contain carboniferous materials. No serious exploration attempts have been made in these areas, and outside of the Yakutat area, the USGS considers the southeast region to have negligible hydrocarbon potential (Bruns 1996a; Selkregg 1974c).

3.1.1.2 Occurrence Potential

The potential for the occurrence of oil and gas resources in the Ring of Fire planning area is summarized on Figures G-15 through G-18. Criteria for this mapping effort were developed by URS and BLM geologists (Diel 2004) in accordance with BLM guidance for fluid minerals (1990). The purpose of these maps is to show potential resource areas; they are not intended to imply the potential for development or economic extraction of the resource. Development potential for the Ring of Fire planning area is addressed in Chapter 4.

Potential Ratings. The occurrence potential ratings for oil and gas resources are based on the following rationale:

<u>High Oil and Gas Potential:</u> BLM (1990) indicates that areas of high oil and gas potential should be based on their inclusion in an oil and gas play defined by the USGS National Assessment, or in the absence of a USGS play, the demonstrated presence of a source, reservoir, and trap. Since the 1995 USGS National Assessment addressed all areas of Alaska for conventional oil and gas resources, and no other viable play combinations were identified during literature review for this document, the high potential category for the Ring of Fire planning area is based on the USGS play areas as shown on Figures G-15 through G-18. In accordance with BLM (1990) guidance, these designations are made regardless of USGS probability ratings for each play area.

<u>Medium Oil and Gas Potential</u>: BLM (1990) indicates similar geologic requirements for this category as in the high category (i.e., source, reservoir, trap), but that the analysis can be based on geologic inference or indirect evidence. Areas within the Ring of Fire planning area were mapped as having medium potential if they lay outside of a USGS play, but within the boundaries of an oil and gas basin mapped by Ehm (1983).

<u>Low Oil and Gas Potential</u>: These are areas where one or more play attributes (e.g., source, reservoir, trap) may not be present (BLM 1990). Areas of the Ring of Fire planning area were considered to have low oil and gas potential where sedimentary rocks are present outside of the identified oil and gas basins.

<u>No Oil and Gas Potential</u>: Areas of igneous, metamorphic, and volcanic rock within the Ring of Fire planning area were generally considered to have no oil and gas potential. Areas of low and no potential are combined on Figures G-15 through G-18 for expediency; the division between the two categories, that is, areas of sedimentary versus non-sedimentary rocks, is provided on the geologic maps on Figures G-6 though G-9 and Table G-1.

Confidence Level. BLM (1985 and 1990) guidance suggests that level of confidence or certainty in the accuracy of mineral potential interpretation be indicated through standard cartographic techniques. Confidence level is indicated on Figures G-15 through G-18 as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid or continuous lines. High potential areas based on USGS plays with high probabilities in areas of proven reserves (e.g., Cook Inlet Tertiary plays) were considered to fall into this category.
- Areas where direct evidence is available but is quantitatively minimal are indicated by long-dashed lines. For example, high potential areas based on USGS plays with low probabilities (e.g., Alaska Peninsula and Yakutat area) were considered to fall in this category.
- Areas where indirect evidence alone supports the interpretation are indicated by short-dashed lines. Boundaries between areas of medium potential (within basins) and low-no potential (outside of basins) are mapped in this manner.

Summary. In accordance with BLM (1990) guidance, high potential ratings were given to all USGS plays, regardless of probability assigned by USGS; relative probabilities are indicated on the maps by solid versus dashed play boundaries. Plays of the Alaska Peninsula, Cook Inlet-Susitna Basin, Copper River Basin, and Yakutat area are all considered to have high occurrence potential. Small slivers of medium potential were mapped around the north, west, and northeast margins of Cook Inlet Basin where play area boundaries lie within basin boundaries. All other areas of the Ring of Fire planning area were considered to have low to no oil and gas potential.

3.1.2 Coal

3.1.2.1 Known Deposits, Fields, and History

Sedimentary rocks with coal deposits are known to occur in a number of areas within the Ring of Fire planning area, including the Alaska Peninsula, the Kodiak region, Cook Inlet-Susitna basin, and scattered areas of the southeast region. Figures G-19 through G-21 depict data used to identify the extent of coal occurrence within the Ring of Fire planning area, including: coal fields and districts mapped by Merritt and Hawley (1986); coal-bearing sedimentary units mapped by Beikman (1980); a coal-bearing mineral terrane unit mapped by Resource Data Center, Inc. [RDI] *et al.* (1995); sedimentary basin boundaries from Ehm (1983); coal occurrences identified in BLM's Mineral Availability System/Mineral Industry Location System (MAS/MILS) database (USBOM 1995); and coal occurrence potential (described in Section 3.1.2.2). These data, as well as the production history of existing coal fields, are summarized below by geographic region.

The term "district" was originally assigned to coal fields identified under the Bituminous Coal Act of 1937, which included all mines in Alaska. Although the act was later repealed, district designations remained in usage in many areas of the U.S. (USDOE 2004b). The term district is also used in Alaska (e.g., Merritt and Hawley 1986) to refer to subunits within larger coal fields. Thus, areas referred to as coal districts may be smaller, and of lesser historical importance, than coal fields. Terms of coal classification by rank, and a summary of geochemical data for each coal province, are provided in Section 2.4.2.

Alaska Peninsula/Aleutian Chain Region

The Aleutian Chain is not known to contain coal-bearing sedimentary rocks. Several Tertiary sedimentary units, which are coal-bearing elsewhere in Alaska, outcrop on Attu, Amchitka, Umnak, and Unalaska Islands (Figure G-6, Table G-1). These formations, however, consist primarily of siliclastic and volcaniclastic deposits in the Aleutians, and likely do not contain coal layers (USFWS 1988; Vallier *et al.* 1994).

The Alaska Peninsula contains two distinct coal-bearing basins. Coals deposited in the Cretaceous located along the southeast half of the peninsula are primarily bituminous rank, while coals deposited in the Tertiary are located mostly along the northwest side of the peninsula and are bituminous to lignite in rank (Smith 1995) (Figure G-19, Section 2.4.2). The two basins have different structural and depositional histories, and are separated by a regional unconformity (Section 2.3.1).

The Herendeen Bay and Chignik coal fields contain coals of the upper Cretaceous Coal Valley Member of the Chignik Formation (Figure G-10). Similar coal-bearing rocks extend from these areas northeast into the Ugashik district. The Coal Valley Member is laterally discontinuous along the peninsula, becoming thickest at Herendeen bay and absent in other areas. Coals of the Herendeen Bay field outcrop in up to 17 individual beds typically less than 2 ft thick, which are distributed over a 1,250-ft stratigraphic section, and occupy an area of over 1,100 square miles. Coals of the Chignik field occupy over 150 square miles and are typically less than 9 ft thick (Merritt 1986a; Smith 1995).

Tertiary coal on the Alaska Peninsula occurs in the Tolstoi, Stepovak, and Bear Lake Formations (Figure G-10). The coal district on Unga Island is composed of lignite of the Miocene Bear Lake Formation. The Unga Island district occurs over an area less than 40 square miles in seams ranging from 1½ to 3 ft thick (Merritt 1986a). Tertiary coal-bearing rocks are widely distributed at depth in the coastal area along Bristol Bay based on strata encountered in oil exploration wells (Merritt and Hawley 1986). These strata subcrop in an area over 250 miles long and extending at least 35 miles offshore into the North Aleutian Basin (Figure G-19).

The coal fields and districts of the Alaska Peninsula were mined by small scale operations in the late 1800s and early 1900s (DGGS 1993a; Merritt 1986b; Wahrhaftig *et al.* 1994). DGGS (1993a) indicates identified reserves of 130 million tons and 230 million tons for the Herendeen and Chignik fields, respectively, and 1,500 million tons of hypothetical reserves in each of these fields. Past production of these two fields has been less than 100,000 tons (Merritt 1986a). Identified resources of the Unga Island Field are estimated at 70 million short tons (Merritt 1986a). Merritt (1986c) rates the coal potential of the Chignik, Herendeen, and Unga Island areas as high, and indicates that while these areas have proven reserves, they are likely not large enough for the export market.

Kodiak Region

Coal is known to occur on Sitkinak and Sitkalidak Islands off the southeast side of Kodiak within the Oligocene Sitkinak Formation (Figures G-7, G-11, and G-19). On Sitkinak Island, outcropping coal beds are 10 to 12 ft thick. Merritt (1984) lists the coal development potential of Sitkinak Island as low. Additional occurrences of coal have been mapped within other Tertiary rocks along southeast Kodiak Island and within upper Cretaceous rocks of central Kodiak Island, although the extent of these deposits is unknown (Merritt and Hawley 1986). Alluvial coal clasts are known to occur in a fossil beach deposit near the Ayakulik River on southwest Kodiak Island (USFWS 1987).

Southcentral Region

Several major coal fields occur in the Cook Inlet-Susitna Basin of south central Alaska. From northwest to southeast, these include the Yentna, Susitna, Matanuska, Beluga, and Kenai fields (Figure G-20). These fields accumulated in peat-forming swamp deposits that were part of a large Tertiary river system, in which Cook Inlet was the main trunk stream, and the Susitna and Matanuska Valleys were tributaries (Wahraftig *et al.* 1994).

Yentna Coal Field. The Yentna Field occurs in the Susitna lowland of the northern part of the basin. The coal is subbituminous and occurs within the Oligocene to Miocene Tyonek Formation (Figure G-13). The Yentna field is comprised of three coal districts; from south the north, these are the Canyon Creek, Johnson Creek, and Fairview Mountain districts. Coal beds reach up to 50 ft thick in the Fairview Mountain district. Identified resources to a depth of 250 ft in the combined Johnson Creek and Canyon Creek districts are more than 500 million short tons (Merritt and Hawley 1986). Only minor production has occurred in the Yentna field in the past.

Susitna Coal Field. The Susitna field contains two districts: the Susitna Flats district to the west and the Little Susitna district to the east. The coal is borderline bituminous-subbituminous and occurs within the Miocene- to Pliocene-age Beluga and Sterling Formations (Figure G-13). The Susitna Flats district occupies a broad area beneath Quaternary overburden and straddles the Castle Mountain Fault. North of the fault, coal seams at depth are up to 15 ft thick within a

2,000-ft thick section overlying basement; just south of the fault, oil well logs show a total of about 300 ft of coal in 37 seams over more than 8,500 ft of strata (Merritt and Hawley 1986). The Little Susitna district is located near surface to the east of the Susitna Flats district. A strip mine operated for several years near Houston in this coal district, depleting much of the recoverable resource. Merritt and Hawley (1986) and Merritt (1986a and 1986b) indicate that the Little Susitna district has a potential remaining resource of 14.7 million tons, but has low development potential because most seams are too thin to be considered mineable (less than 2 ft thick).

Matanuska Coal Field. The Matanuska field underlies much of the Matanuska Valley in the northeast part of south central Alaska. Coal deposits in this area occur within the folded and faulted Chickaloon Formation of Paleocene to lower Eocene age (Figure G-13), and have been well-defined by Barnes and Payne (1956) and Barnes (1962). The Matanuska field is comprised of five coal districts; from southwest to northeast, these are the Wishbone Hill, Young Creek, Castle Mountain, Chickaloon, and Anthracite Ridge districts. Each district covers roughly a 10- to 20-square mile area. High rank anthracite coals occur in the northeast part of the field, and change to lower rank bituminous coals towards the southwest (Merritt and Hawley 1986; DGGS 1993a).

Extraction from the Matanuska field began in about 1913. In 1916, the Alaska Railroad was built through the southcentral region to access the Matanuska field as well as other fields to the north (Barnes and Payne 1956; Merritt 1986b). Seven separate mining operations operated in the field between 1913 and 1968, when natural gas from Cook Inlet replaced coal use in the Anchorage area. Minor production continued until 1982 for local needs. Total past production was about 7.5 million tons, mostly from the Evan Jones Mine in the Wishbone Hill district. DGGS (1993a) estimates remaining identified reserves in the combined Wishbone Hill, Chickaloon, and Anthracite Ridge districts to be about 150 million tons.

Beluga Coal Field. Potentially mineable subbituminous coal occurs in three districts of the Beluga field, referred to as the Capps, Chuitna, and Threemile districts. Coal in the Capps and Chuitna districts lies within the Tyonek Formation, while coal of the Threemile district lies within the Miocene Beluga Formation (Figure G-13). Individual coal beds range from approximately 10 to 40 ft thick in these districts (Merritt and Hawley 1986). Drilling in the 1980s proved up measured reserves of approximately 1.2 billion tons of coal in the Chuitna district (Merritt 1986b). Identified resources of the Beluga Field as a whole are estimated at ten billion short tons (Merritt and Hawley 1986). Only minor production has occurred in the Beluga field in the past (Merritt 1986a).

Kenai Coal Field. The Kenai field consists of three subbituminous coal districts: Kenai Onshore, Kenai Offshore, and the Seldovia-Port Graham district. Most of the near-surface coal in the Kenai Onshore and Offshore districts lies in 2.5- to 20-ft thick beds within the Beluga and Sterling Formations (Figure G-13). Coal-bearing strata are also present at depth in the Tyonek Formation within the Kenai Onshore and Offshore districts, and Tyonek Formation coals outcrop in the Seldovia-Port Graham district (Merritt and Hawley 1983).

The Kenai Onshore district occupies an area of over 2,000 square miles. Identified resources of the Kenai Onshore district total approximately 320 million short tons, with hypothetical resources estimated at 35 billion short tons. Up to 1,500 billion short tons of hypothetical coal resources are estimated to underlie parts of Cook Inlet up to depths of 10,000 ft (Merritt 1986a; Merritt and Hawley 1986). The first coal extraction from the Kenai field began in the late 1800s with small mining operations in the Homer and Port Graham areas (Merritt 1986b). Total past production in the Kenai field has been less than 100,000 tons.

Southeast Region

Several localized areas in the southeast region are known to contain coal. Coal occurs within Tertiary continental rocks of the Kootznahoo Formation in the Angoon, Admiralty, and Kuiu coal districts (Table G-1; Figures G-9 and G-21). As indicated in Section 2.4.2, coals of the Admiralty and Angoon districts are considered bituminous, and Kuiu district contains lignite (Merritt and Hawley 1986). The largest of these deposits is in the Angoon district, where 2- to 3-ft thick coal beds are exposed on the north and south sides of Kootznahoo Inlet, and are estimated to extend over a 20-square mile area (Selkregg 1974c). Isolated occurrences of Tertiary lignites have also been reported near Yakutat and Lituya Bays, in the northeast Glacier Bay area, in the northeast corner of Admiralty Island, on southwest Baranof Island, and at Kasaan Bay on Prince of Wales Island (Merritt 1986b; Merritt and Hawley 1986).

Several small-scale mines operated on Admiralty Island in the late 1800s and early 1900s. One of those in the Angoon district operated from an inclined shaft dug to a depth of several hundred ft (Merritt 1986b; Selkregg 1974c). Merritt (1986b) and Merritt and Hawley (1986) suggest that, except for local use, the coal districts of the southeast region have low development potential due to their small size.

3.1.2.2 Occurrence Potential

The potential for coal occurrence in the Ring of Fire planning area is summarized on Figures G-19 through G-21. Criteria for this mapping effort were developed by URS and BLM geologists (Diel 2004) in accordance with BLM guidance documents (BLM 1985 and 1990). The purpose of these maps is to show potential resource areas; they are not intended to imply the potential for development or economic extraction of the resource. Development potential for the Ring of Fire planning area is addressed in Chapter 4.

Potential Ratings. The occurrence potential ratings for coal resources are based on the following rationale:

High Coal Potential: BLM (1985) guidance suggests that areas of high mineral potential be demonstrated based on geologic environment, inferred geologic processes, reported mineral occurrences, and known mines or deposits. Within the Ring of Fire planning area, areas were mapped as high coal potential if they are part of a designated coal field or district. These areas generally contain proven or inferred reserves and a history of coal extraction.

Medium Coal Potential: Areas mapped as medium potential include the following: coal-bearing formations mapped by Beikman (1980) that are not included within coal field or coal district boundaries; sedimentary basins mapped by Ehm (1983) that contain coal-bearing rocks; and a coal-bearing mineral terrane unit mapped by RDI *et al.* (1995).

Low Coal Potential: Areas of non-coal-bearing sedimentary rocks located outside of basin boundaries were considered to have low potential for coal.

No Coal Potential: Areas of non-sedimentary rocks were considered to have no coal potential. Areas of low and no potential are combined on Figures G-19 through G-21 for expediency; the division between the two categories (i.e., areas of sedimentary versus non-sedimentary rocks) is provided on geologic maps on Figures G-6 though G-9 and Table G-1.

Confidence Level. BLM (1985, 1990) guidance suggests that level of confidence or certainty in the accuracy of mineral potential interpretation be indicated through standard cartographic techniques. Confidence level is indicated on Figures G-19 through G-21 as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid or continuous lines. High potential areas based on coal fields mapped by Merritt and Hawley (1986) were considered to fall into this category.
- Areas were indicated by dashed lines where either 1) direct evidence of a potential coal resource is available but is quantitatively minimal, or 2) indirect evidence is available. These include coal district boundaries where they occur outside of designated fields, as well as all areas included in the medium potential category (coal-bearing formations, mineral terranes, and basin boundaries).

Summary. Areas of high coal potential are found in all regions of the Ring of Fire planning area except for the Aleutian Chain. Coal fields and districts that represent a high potential for coal occurrence are described in Section 3.1.2 by geographic region. Large areas of medium coal potential lie on the Alaska Peninsula, Kodiak region, and southcentral region where coal-bearing formations, basins, or mineral terranes extend outside of, or in between, high potential areas. Areas of non-coal-bearing sedimentary rocks and non-sedimentary rocks are designated as having low to no coal potential on Figures G-19 through G-21.

3.1.3 Coalbed Natural Gas

CBNG, also known as coalbed methane, occurs in association with coal-bearing formations in which the gas is generated. The occurrence of coal in the Ring of Fire planning area is summarized in Section 3.1.2 and depicted on Figures G-19 through G-21. These figures also show State of Alaska non-competitive shallow gas leases issued under a recent program intending to provide incentive to locate natural gas, including CBNG, from depths less than 3,000 ft, which can be delivered to remote consumers at less cost than alternative energies (ADNR Division of Oil and Gas 2004b and 2004d). The shallow gas leasing program was repealed by the State in December 2004 (ADNR Division of Oil and Gas 2005). Conventional gas fields, leases, wells, and plays are combined with oil data on Figures G-15 through G-17, and described in Section 3.1.1. Criteria used for evaluating the occurrence potential of CBNG, as well as a summary of potential resources by geographic region, are summarized below.

3.1.3.1 Conditions for Occurrence

Geologic conditions required for the occurrence of CBNG are as complex as conditions for the occurrence of conventional oil and gas. Detailed basin analysis and an understanding of the interplay between many geologic factors are generally required to delineate the presence and origin of CBNG (Tyler *et al.* 2000). Although near-surface coal has been studied and commercially utilized in Alaska for over 100 years and most surficial coal occurrences have been mapped, subsurface coal containing potential CBNG resources have received considerably less attention (Smith 1995). Although the USGS has developed CBNG plays for the contiguous U.S. (Rice 1996), they have not yet been assessed for Alaska. A review of contributing factors for CBNG occurrence was conducted to provide an understanding of the CBNG potential within the Ring of Fire planning area.

High CBNG productivity tends to occur under the following conditions: 1) thick, laterally continuous coal beds; 2) high thermal maturity or rank; 3) adequate permeability; 4) groundwater flow through coals; 5) flow direction perpendicular towards groundwater barriers or structural/stratigraphic traps; 6) additional sources of gas beyond that which is generated during coalification; 7) accumulation of gas against traps and groundwater barriers; and 8) adequate pressure regime, i.e., depths between about 500 and 6,000 ft (Belowich 2003; DGGS 2003; Dolan 2002; Rice 1996; Rice *et al.* 1996; Tyler *et al.* 2000).

Unlike conventional oil and gas, coal beds function as both the source and reservoir for CBNG, such that their thickness and distribution within a basin is important to understanding the extent of the resource. Large amounts of gas are generated during coalification by both biogenic and thermogenic processes, the gas being sorbed onto internal surfaces of the microporous coal (Rice *et al.* 1996). As indicated in Section 2.4.2, coals must reach a certain threshold of thermal maturity before significant volumes of thermogenic methane can develop. Although high rank coals generally have higher gas contents, gas content is not determined by rank alone. Gas content can be enhanced by the generation of secondary biogenic gas, or by groundwater migration of gas towards traps or no-flow boundaries. Permeability in coal beds is determined by fractures (or cleats), which are largely controlled by tectonic setting. Cleats function as pathways for migration of gas and water to the wellhead (Rice *et al.* 1996; Tyler *et al.* 2000). Although thermal maturity increases at deeper depths, shallower depths contain less compressed gas and greater permeability and storage capacity in cleats. Because of their plastic nature, coal beds tend to lose permeability and have non-economic production levels below about 4,000 to 6,000 ft, and in areas of high structural deformation (Belowich 2003; Dolan 2002; Rice *et al.* 1996). At depths shallower than about 500 ft, gas contents are generally too low for commercial production (Rice 1996). The direction of groundwater flow relative to potentially trapping mechanisms is important, because the largest possible area of flow is intercepted when flow direction is orthogonal (perpendicular) to traps, maximizing the opportunity for gas resorption and accumulation (Tyler *et al.* 2000).

CBNG can be developed in settings both in association with, and away from, underground coal mines. Pressure reduction during coal mining results in the release of CBNG, which is commonly vented to the atmosphere to prevent explosive hazards. Different types of wells, including vertical gob wells and horizontal wells drilled from inside mines, have been used in the contiguous U.S. to recover CBNG from underground mines. The largest resources of CBNG, however, are typically away from coal mining areas where the coal layers are deeper. Generally, vertical wells drilled in this type of setting use a variety of completion techniques to enhance permeability, such as hydraulic fracturing (Evergreen Resources 2003b; Rice 1996). Water is commonly produced from CBNG wells, especially during early stages of production when dewatering is required to reduce reservoir pressure and initiate gas desorption from the coal (Rice *et al.* 1996).

3.1.3.2 CBNG Occurrence by Region

The following is a summary of the known or suspected occurrence of CBNG in subsurface coal deposits within each region of the Ring of Fire planning area.

Alaska Peninsula/Aleutian Chain Region

As indicated in Section 3.1.2.1, the Aleutian Chain is not known to contain coal-bearing sedimentary rocks. The Cretaceous and Tertiary coal-bearing sedimentary rocks and coal fields of the Alaska Peninsula are described in Section 3.1.2.1 and shown on Figure G-19. The rank and gas-generating potential of these rocks are described in Section 2.4.2.

CBNG in Cretaceous Strata. Smith (1995) and Tyler *et al.* (2000) describe the CBNG potential of Cretaceous coals in the Chignik and Herendeen Bay areas of the Alaska Peninsula. The coals occur in thin individual beds, are laterally discontinuous, highly cleated, and moderately to intensely deformed. Structural complexity in the Chignik area is typified by compressional folding, overthrusting, and high-angle faulting, with the trend of structural features subparallel to the axis of the peninsula.

Chignik area coals encountered in oil exploration wells at depths greater than 4,000 ft are low- to high-volatile bituminous rank. These coals are within or approaching the range of thermogenic gas generation, and have shown significant gas shows on mudlogs. Coals of similar rank are found in outcrops in the Chignik and Herendeen Bay areas, indicating considerable uplift since maximum burial. The permeability of the cleat system could be enhanced in the uplifted areas, but high stresses related to present-day tectonism could also result in low permeabilities. The rainy climate and presence of groundwater in one of Chignik's abandoned mines suggest that the coals may have the recharge potential and permeability to potentially enhance CBNG accumulation with secondary biogenic gas (Tyler *et al.* 2000).

Smith (1995) and Tyler *et al.* (2000) conclude that the thin beds, discontinuous strata, and structural complexity of the Cretaceous coals would make subsurface exploration for large scale CBNG operations difficult in these areas. Exploration for localized CBNG for village use may prove viable, but costs and risks would be high due to the depth, structural and stratigraphic complexities, and potentially high dewatering costs.

In 1996, the State of Alaska DGGS established a program to evaluate the potential for CBNG to meet the energy needs of roadless communities that currently depend on fuel oil for heating and power generation (Clough 2001). Based on the work of Tyler *et al.* (2000), DGGS is further evaluating three coal basins in Alaska, one of which is in the Chignik area of the Alaska Peninsula. As part of this program, a water supply well drilled by the Alaska Native Tribal Health Consortium near Chignik Lake in 2002 was monitored by DGGS for potential coal beds and CBNG to a depth of 750 ft (DGGS 2003). No coal beds were encountered at these depths; however, these results do not rule out the potential for Cretaceous coal beds at deeper levels in the area (Clough 2004).

CBNG in Tertiary Strata. Tertiary coals of the Unga Island district and beneath the Bristol Bay coastal area (North Aleutian Basin) are generally lower rank than the Cretaceous coals. Of the three Tertiary coal-bearing formations of the peninsula (Tolstoi, Stepovak, and Bear Lake), only the Tolstoi Formation contains bituminous coals of sufficient rank for thermogenic CBNG generation. Minor to good gas shows were encountered in Tertiary coals during drilling of exploration wells in the Port Heiden area on Bristol Bay. Gassy coal sections within the Tolstoi Formation were encountered in wells between 5,800 and 10,400 ft (Smith 1995; Tyler *et al.* 2000).

Smith (1995) concludes that although most Tertiary coal-bearing strata on the peninsula are too low rank to have good gas potential, it is possible that if Tolstoi Formation coals were found in structurally high areas within the North Aleutian Basin above 5,000 ft in depth, they may have some CBNG potential. The low maturity of most Tertiary coals of the peninsula indicates that the area may be favorable for secondary biogenic gas (Molenaar 1996a; Molenaar 1996b). It is also possible that groundwater flow through the basin may enhance gas contents through migration to traps.

Kodiak Region

As indicated in Section 3.1.2.1, with the exception of several known outcrops in the southeast part of Kodiak, the extent and rank of coal layers within the coal-bearing sedimentary rocks shown on Figure G-19 are largely unknown. Based on very limited information, the potential for CBNG occurrence on Kodiak is estimated to be similar to that of the coal itself.

Southcentral Region

The major coal fields and districts of the Cook Inlet-Susitna Basin are described in Section 3.1.2.1 and shown on Figure G-20. Coal is found in several Tertiary formations in the basin, including the Chickaloon, Tyonek, Beluga, and Sterling Formations (Figure G-13). Of these, the Oligocene-Miocene Tyonek Formation and the Paleocene Chickaloon Formation have the highest CBNG potential (Smith 1995). The Tyonek Formation is widespread across Cook Inlet-Susitna basin, comprising the large coal fields along the west side of the basin (Yentna and Beluga fields), and is found at depth in the Kenai field. The Chickaloon Formation is limited to the northeast portion of the basin in Matanuska Valley.

Cook Inlet Basin. The cumulative thickness of Tyonek Formation coal ranges from 200 ft along the eastern edge of Cook Inlet basin, to more than 1,200 ft in two areas along the west coast of Cook Inlet: near the north end of Trading Bay southwest of Tyonek, and near the north end of Redoubt Bay (Wahrhaftig *et al.* 1994). These coal thicknesses are considered very high compared to CBNG fields in the contiguous U.S. (Smith 1995).

Because of post-depositional Holocene uplift along the margins of Cook Inlet Basin, older coal-bearing strata with higher thermal maturities are exposed along its margins, making these areas attractive for CBNG exploration. Vitrinite reflectances of 0.6 percent, marking the threshold of thermal maturity needed for CBNG generation (Section 2.4.2), are reached at a depth of approximately 15,000 ft near the axis of Cook Inlet Basin and at roughly 5,000 ft along its margins (Smith 1995). The presence of numerous conventional gas fields containing migrated gas from both thermogenic and biogenic sources (Table G-2, Section 2.4.2) suggests that migrated gas may also be available to enhance gas contents in coal beds through groundwater flow and trapping. In May 2004, a state lease sale in upper Cook Inlet indicated a high level of industry interest in onshore tracts that may be targeting CBNG deeper than 3,000 ft along the west side of Cook Inlet basin southwest of Tyonek, as well as possibly a mixture of conventional gas reservoirs and coalbed accumulations on Kenai Peninsula (ADN 2004d). The State issued several shallow gas leases in the Homer area in 2003 totaling approximately 22,600 acres (ADNR Division of Oil and Gas 2005).

Susitna Basin. Susitna Basin is a smaller, shallower, and younger extension of Cook Inlet Basin, and is separated from Cook Inlet Basin by the Castle Mountain Fault (Figure G-20). Like the Cook Inlet Basin, the uplifted basin margins around Susitna Basin are considered highly prospective for CBNG (Smith 1995). Exploratory wells drilled in the deeper central part of the Susitna Basin encountered Tyonek Formation coals with good gas shows between 11,700 and 13,700 ft (Smith 1995). In 2003 and 2004, several exploratory coreholes likely targeting Tyonek Formation CBNG along the basin margin were drilled by Evergreen Resources along the Parks Highway (ADNR Division of Oil and Gas 2003b; Evergreen Resources 2003a).

Castle Mountain Fault Area. The Castle Mountain Fault is an active, north-dipping, oblique (right lateral) thrust fault, which separates the Susitna Basin to the north, from the Cook Inlet basin to the south (Plafker *et al.* 1993). Areas along both sides of the fault from Houston to Sutton are considered highly prospective for CBNG due to a combination of high rank Tyonek and Chickaloon Formation coals at depths less than 5,000 ft (Smith 1995), as well as possible fault-parallel fold traps similar to those mapped at the surface in the Matanuska coal field (Barnes 1962; Barnes and Payne 1959). On the south side of the fault, coal-bearing rocks form a southwest-dipping wedge, with the depth to mature coals (Ro = 0.6 percent) ranging from zero near Palmer where mature coals outcrop at the surface, to 2,000 to 3,000 ft near the Parks Highway, to 10,000 ft further southwest near the Susitna River mouth (Smith 1995).

The presence of CBNG in the Chickaloon Formation was documented by mine explosions in the Matanuska Mine in 1937 and 1957. Exploratory oil and gas wells drilled in the 1950s and 1960s in the Houston area just north of the Castle Mountain Fault (Figure G-17) encountered gassy coals and sandstones probably within the Tyonek Formation. In 1994, the State funded a corehole to sample Tyonek Formation CBNG near Wasilla on the south side of the Castle Mountain Fault. Cumulative coal thickness in this hole exceeded 100 ft. The geochemistry of the gas is summarized in Section 2.4.2. Based on the results of this corehole, high-volatile bituminous coals were estimated to be present between 500 and 6,000 ft in the area (Smith 1995).

In 2002, Evergreen Resources drilled two 4-well pilot projects in the Pioneer Unit located on the south side of the Castle Mountain Fault (Figure G-17). All wells penetrated aggregate coal thicknesses greater than 100 ft. The State issued a number of shallow gas leases in this area in 2003 totaling about 230,000 acres (ADNR Division of Oil and Gas 2005). Evergreen announced that the first two pilot projects were probably not capable of commercial production in November 2003. A third pilot project drilled in 2003 tested the potential of the unit's deeper coals (Evergreen Resources 2003b). In 2003 and 2004, Evergreen drilled two exploratory coreholes to further test for CBNG near the fault, one located in the southwest part of the Pioneer Unit and one located about 18 miles to the northeast in the southwest corner of the Matanuska coal field (ADNR Division of Oil and Gas 2004c; Evergreen Resources 2003a). In May 2004, a state conventional gas lease sale in upper Cook Inlet indicated a high level of industry interest in onshore tracts that are likely targeting CBNG further south of the fault between Big Lake and Point MacKenzie (ADN 2004d). The state repealed the shallow gas leasing program in December 2004 (ADNR Division of Oil and Gas 2005).

Southeast Region

As indicated in Section 3.1.2.1 and Figure G-21, several localized areas in the southeast region are known to contain coal. The structure and stratigraphy of related conventional oil and gas plays in the southeast region are described in Section 3.1.1.1.

Gulf of Alaska-Yakutat Basin. The CBNG potential of the eastern Gulf of Alaska-Yakutat Basin (Figure G-21) is highly speculative and hinges on the presence of the Eocene Kulthieth Formation in the subsurface (Figure G-11). The Bering River coal field, located about 150 miles west-northwest of Yakutat (outside of the Ring of Fire planning area), is composed of high rank bituminous to anthracite coals of the Kulthieth Formation. Warhaftig *et al.* (1994) suggests that the thermal maturity of Kulthieth Formation coals is anomalously high compared to other Tertiary strata in Alaska, due to igneous intrusive activity prior to accretion of the Yakutat block to the Alaskan continental margin.

The Kulthieth Formation is more than 4,700 ft thick where it outcrops in the Samovar Hills about 50 miles northwest of Yakutat (Wahrhaftig *et al.* 1994) (Figure G-21). It has also been reported in exploration wells in the Yakutat area (Bruns 1996a; Bruns 1996b) (Figure G-18), and is inferred to be up to 2,000 ft thick beneath the adjacent shelf (MMS 1995). The Kulthieth Formation pinches out to the southeast about halfway between Yakutat and Lituya Bays, where it onlaps a Paleogene high east of the Dangerous River structural zone (Section 3.1.1.1). The depth to the top of the Kulthieth Formation along the nearshore shelf is estimated to range from less than 6,000 ft near the Dangerous River (about 25 miles southeast of Yakutat) to 13,000 ft near Yakutat (MMS 1995).

While coal seams in the Bering River field are up to 60 ft thick and intensely deformed, they are estimated to be thinner and less deformed in the broad subsurface area extending southeast towards Yakutat Bay (Smith 1995). Smith (1995) suggests that CBNG plays may be found in structurally less deformed areas along the coast near the Bering River field. It is possible that this play may also apply to buried structural highs in the coastal area southeast of Yakutat, if Kulthieth coalbeds of sufficient thickness are present.

Central Southeast Region. The Admiralty and Angoon coal districts of the southeast region (Figure G-21) contain bituminous coals of the Eocene- to Miocene-age Kootznahoo Formation (Gehrels and Berg,1992; Merritt and Hawley 1986; Selkregg 1974c). Petrographic similarities between sandstones of the Kooztnahoo and the Kulthieth Formations suggest that they may have similar origins and histories (Wahrhaftig *et al.* 1996). Coal-bearing strata in the Angoon district are known to extend at least several hundred ft into the subsurface (Section 3.1.2.1). Based on the high rank of the coals and their limited extent in this area, the Angoon and Admiralty districts are considered potentially prospective for CBNG for local use.

The potential for CBNG in Kuiu district coals, located on Kuiu, Kupreanof, and Zarembo Islands (Figure G-21), is considered to be limited due to the low rank of the coal (lignite) (Merritt and Hawley 1986).

3.1.3.3 Occurrence Potential

The potential for CBNG occurrence in the Ring of Fire planning area is depicted on Figures G-19 through 21. As described in Section 3.1.3.1, the presence of CBNG resources depends on an understanding of subsurface coal extent and other complex geologic factors. The following criteria incorporate published interpretations of these factors where available, as well as preliminary interpretations based on broad-based criteria for areas where subsurface data are lacking. In the absence of specific BLM guidance for CBNG potential, the criteria below generally follow those outlined in BLM (1990) guidance for fluid minerals that are intended for use in classifying conventional oil and gas potential.

<u>High CBNG Potential:</u> BLM (1990) indicates that areas of high conventional gas potential be based on their inclusion in a play defined by the USGS National Assessment (USGS 1995). USGS has not yet defined CBNG plays for Alaska. Their approach for identifying plays in the contiguous U.S. is based on the geologic conditions described in Section 3.1.3.1; in addition, they provide a qualitative rating of “good,” “fair,” or “poor” based on a combination of these criteria. Under BLM (1990) guidance, all of these plays, regardless of rating, would be considered high potential for the purposes of planning documents. In the absence of a USGS play, BLM (1990) indicates that areas of high potential for conventional gas be based on the demonstrated presence of a source, reservoir, and trap. In the case of CBNG, coal beds provide

both the source and reservoir, and often the trap as well. Based on the above considerations, and the lack of data available to refine CBNG interpretations, most areas of the Ring of Fire planning area with known or suspected high rank coal in the subsurface, regardless of relative risk of CBNG exploration success, were considered high potential.

Section 3.1.3.2 presents various CBNG prospects or plays in the Ring of Fire planning area by geographic region. Areas designated as having high potential for CBNG include the subsurface beneath high rank coal fields and districts, as well as areas adjacent to coal fields where coal-bearing formations extend into the subsurface. High rank was generally considered to be bituminous or greater at the surface, or the potential for bituminous or greater with depth. Other favorable geologic conditions, such as groundwater flow, trapping mechanisms, or other sources of gas, were considered on a regional basis where such information was available.

<u>Medium CBNG Potential:</u> BLM (1990) indicates similar geologic requirements for conventional gas potential in this category as for the high potential category (i.e., source, reservoir, trap), but that the analysis be based more on inference or indirect evidence. Areas within the Ring of Fire planning area mapped as having medium potential include: 1) areas estimated to contain coals of subbituminous to lignite rank at depth; 2) areas where coal-bearing formations are mapped adjacent to coal districts that are not part of designated fields; and 3) areas mapped as coal-bearing sedimentary rocks (Beikman 1980) or coal-bearing mineral terrane (RDI *et al.* 1995) that are located outside of known fields and districts.

<u>Low CBNG Potential</u>: Areas of non-coal-bearing sedimentary rocks were considered to have low potential for CBNG.

<u>No CBNG Potential</u>: Areas of non-sedimentary rocks were considered to have no CBNG potential. Areas of low and no potential are combined on Figures G-19 through G-21 for expediency; the division between the two categories (i.e., areas of sedimentary versus non-sedimentary rocks) is provided on the geologic maps on Figures G-6 though G-9 and Table G-1.

Confidence Level. Confidence level is indicated on Figures G-19 through G-21 as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid or continuous lines. High CBNG potential areas based on coal fields mapped by Merritt and Hawley (1986) fall in this category.
- Areas were indicated by dashed lines where either 1) direct evidence of a potential CBNG resource is available but is quantitatively minimal, or 2) indirect evidence is available. These include coal district boundaries (where they occur outside of designated fields), coal-bearing formations, mineral terranes, and basin boundaries.

Summary. Areas of high CBNG potential were mapped in all regions of the Ring of Fire planning area except for the Aleutian Chain. These include areas of Cretaceous strata beneath and adjacent to the Herendeen Bay and Chignik coal fields, Cretaceous strata beneath the Ugashik coal district, and areas of Tertiary strata beneath the Bristol Bay coastal plain on the Alaska Peninsula (Figure G-19); the Cook Inlet and Susitna Basins of the southcentral region (Figure G-20); the Gulf of Alaska-Yakutat Basin, and the areas beneath the Angoon and Admiralty coal districts of the southeast region (Figure G-21). Areas of medium CBNG potential lie on the Alaska Peninsula, Kodiak region, and southeast region where coal fields or districts are estimated to be low rank at depth; and where coal-bearing formations, basins, or mineral terranes extend outside of, or in between, high potential areas. Areas of non-coal-bearing sedimentary rocks and non-sedimentary rocks are designated as having low to no CBNG potential on Figures G-19 through G-21.

3.1.4 Geothermal

3.1.4.1 Known Deposits and Occurrences.

Geothermal resources of varying temperatures are known to occur throughout much of the Ring of Fire planning area. Thermal springs are the surface manifestation of subsurface hydrothermal systems, where heat is transferred to the surface primarily by convective circulation of fluids, rather than by thermal conductance through solid rock.

Geothermal systems have been classified by USGS according to their subsurface temperatures and potential uses: they are considered high temperature systems where subsurface temperatures are greater than 150 degrees Celsius (^{o}C), moderate temperature systems between 90^{o}C and 150^{o}C, and low temperature systems where less than 90^{o}C (Motyka *et al.* 1983). This classification is based on the concept that temperatures greater than 150^{o}C are generally required for the generation of electricity; systems in the mid-range are better suited to space heating, agriculture, and industrial applications with some possibility of electricity production from binary generating plants; and low temperature systems may be useful in the immediate vicinity of the resource for space heating, agricultural, or aquacultural uses (Turner *et al.* 1980).

High-Temperature Systems. High-temperature geothermal resources are known or suspected to occur within the Ring of Fire planning area in regions of Quaternary igneous activity (Figures G-22 through G-25). These systems are typically associated with shallow silicic volcanism on the flanks of, or in the calderas of, active stratovolcanoes (Turner *et al.* 1980). These include the volcanoes of the Aleutian arc, the Alaska Peninsula, the west side of Cook Inlet, and the Edgecumbe volcanic field along the western edge of the southeast region. Estimates of reservoir temperatures in these areas have been derived either from direct measurement in exploratory holes, or from estimates based on the geochemistry of thermal springs (Motyka *et al.* 1993; Selkregg 1974b; Turner *et al.* 1980).

A number of publications (e.g., Motyka *et al.* 1983 and 1993; Turner *et al.* 1980; USFWS 1988) document at least 13 sites in the Aleutian Chain with high-temperature reservoirs. These include sites near population centers or small villages such as Adak, Atka, Umnak (Nikolski), Makushin (Unalaska), and Akutan, with estimated subsurface temperatures in the range of 160^{o}C to 300^{o}C; as well as others located in more remote areas such as Great Sitkin and Korovin volcanoes. Three volcanoes on the Alaska Peninsula, Pavlov (Mount Emmons), Mount Veniamanof, and Mount Chignagak, are estimated to have high-temperature systems (Motyka *et al.* 1993; USFWS 1985). Thermal springs and fumeroles on Mount Augustine and Mount Spurr along the west side of Cook Inlet exhibit temperatures and geochemical signatures potentially indicative of high-temperature subsurface systems (Motyka *et al.* 1983; Wescott *et al.* 1985). Motyka *et al.* (1983) suggest that Mount Edgecumbe volcanic field in the southeast region has the potential for high-temperature subsurface systems, based on favorable geology and the presence of a caldera, although no fumeroles or hot springs are present at the surface.

Moderate- to Low-Temperature Systems**.** Motyka *et al.* (1993) report four sites in the Aleutians and Alaska Peninsula with moderate temperature geothermal systems, and six sites with low temperature systems. These include sites near Akutan, Unalaska, Cold Bay, and Port Moller.

Several exploratory oil wells drilled in the Lower Susitna Basin area of the southcentral region indicate the presence of a low-grade, deep, hot-water aquifer that could potentially be tapped for direct use (Motyka *et al.* 1983; Turner *et al.* 1980; Miller 1994). Several moderate and low-temperature systems occur in the southeast region where hydrothermal waters circulate and become heated along deep fractures and faults at the margins of older plutons. These type of systems are present on Chichagof and Baranof Islands as evidenced by at least nine thermal springs; in the Stikine River area northeast of Wrangell; and in the Bell Island and Bradfield Canal areas north of Ketchikan, where reservoir temperatures are estimated in the range of 125 to 135 ^{o}C (Motyka *et al.* 1983; Motyka and Moorman 1987).

3.1.4.2 Prospects and Leases

Past Prospects and Uses. Several areas of the Ring of Fire planning area have been investigated for potential development of geothermal resources for electrical power generation, but none have been developed in the region to date. The high-temperature reservoirs of the Aleutians and Alaska Peninsula have been estimated to contain between $13x10^{18}$ to $1,440x10^{18}$ joules of thermal energy each (Miller 1994). Motyka *et al.* (1993) estimate that the combined 30-year electrical production potential of the Aleutian arc is greater than 1,000 megawatts (MW).

In the early 1980s, the State funded investigations of several geothermal areas of Alaska in an effort to stimulate public interest in the resource as a viable energy option for the State (Turner *et al.* 1980). An extensive exploration project took place on Unalaska Island in the early 1980s to investigate the potential for tapping thermal waters flanking Makushin volcano. Republic Geothermal (1985) estimated that the Makushin reservoir was capable of generating 7 to 13 MW for over 500 years. They also concluded that a geothermal power system with diesel generators as backup, would be more economic than the use of diesel generators alone. A similar conclusion was reached in preliminary studies of geothermal resources on Adak, based on analyses of three resource applications, including a 10 MW binary power plant. Electric power production potential was estimated for Akutan Island and the Geyser Bight area of Umnak Island to be 9.2 MW and 132–225 MW, respectively, for a 30-year period (Motyka and Nye 1985; Nye *et al.* 1992).

Recent interest in alternative power sources to supply the southcentral region and the Railbelt grid has resulted in completion of the initial phase of a USDOE-funded geothermal energy assessment project for Mount Spurr (Turner and Wescott 2004). The results of these studies suggest the presence of a geothermal system at a depth of about 2,000 ft on the south flank of Crater Peak, with additional geophysical and geochemical surveys recommended to better define the extent of potential reservoirs prior to drilling. Any future drilling in this area would need to consider angled drilling to mitigate volcanic hazards.

Several low- to moderate-temperature thermal springs in the southeast region have been developed for various local uses, including tourism, community bathhouses, agriculture, aquaculture, and heating of local dwellings. These sites include the communities of Bell Island, Tenakee Springs, Baranof, and Goddard (near Sitka) (Motyka *et al.* 1983; Turner 1980). A shallow warm-water aquifer delineated at Summer Bay on eastern Unalaska Island was found to be too low in temperature for direct-heat applications (Motyka *et al.* 1993). Selkregg (1974c) noted industry interest in geothermal potential at Augustine Island in Lower Cook Inlet in the early 1970s, but the area was never developed. Similarly, the State leased two tracts at Mount Spurr in the early 1990s for potential hydroponic gardening development, but no development has taken place (Motyka *et al.* 1993).

Known Geothermal Resource Areas (KGRAs) and Leases. KGRAs are land areas designated by BLM where it has been determined that persons knowledgeable in the field of geothermal development would spend money to develop the resource (43 Code of Federal Regulations [CFR] 3200.1). BLM determines the boundaries of a KGRA based on geologic and technical evidence, proximity to wells capable of commercial production, and the existence of a competitive interest, that is, where two or more parties apply for leases. KGRAs typically encompass a geologic structure in which geothermal water or steam has been discovered by drilling and determined to be productive (43 CFR 3203.11).

There are currently two KGRAs in the Ring of Fire planning area. These are located at Okmok Caldera and Geyser Bight Valley on Umnak Island in the eastern Aleutians (Diel 2004; Motyka *et al.* 1983). In the absence of an established KGRA, BLM may issue a noncompetitive lease to the first qualified applicant, or determine if overlapping lease applications warrant converting the land to a KGRA (BLM 2001).

3.1.4.3 Occurrence Potential

The potential for occurrence of geothermal resources in the Ring of Fire planning area is summarized on Figures G-22 through G-25. Criteria for this mapping effort were developed by URS and BLM geologists (Diel 2004) in accordance with BLM guidance documents (BLM 1985 and 1990). The purpose of these maps is to show potential resource areas; they are not intended to imply the potential for development or economic extraction of the resource. Development potential for the Ring of Fire planning area is addressed in Chapter 4.

Potential Ratings. The occurrence potential ratings for geothermal resources are based on the following rationale:

<u>High Geothermal Potential</u>: BLM (1990) indicates that high geothermal potential areas should include existing KGRAs, or areas where the presence of a hydrothermal convection system is well demonstrated by geological evidence. Within the Ring of Fire planning area, areas were mapped as high potential where Quaternary volcanism is present, as well as thermal features such as hot springs, fumaroles, vents, or geysers. Thermal springs with surface temperatures greater than 50^{o}C were included in the high potential category.

<u>Medium Geothermal Potential</u>: Areas were mapped as having medium potential where Quaternary to Late Tertiary volcanism is present, but thermal springs greater than 50^{o}C or other surface features are absent. Hot springs with surface temperatures less than 50^{o}C were included in this category.

<u>Low Geothermal Potential</u>: Low potential areas include broad regions of potential thermal waters mapped by Motyka *et al.* (1983). These areas are described as being favorable for future exploration and discovery of thermal waters at temperatures sufficient for direct-heat applications. The regions are defined on the basis of geologic evidence such as youthful volcanism, tectonic trends, thermal spring activity, mineralization, and seismicity. Motyka *et al.* (1983) acknowledge that probably only small areas within these regions are likely to be underlain by usable thermal waters.

<u>No Potential/Not Determined</u>: According to BLM (1990), the absence of geothermal potential should be demonstrated based on physical evidence or documentation in the literature. Portions of the Ring of Fire planning area outside of the potential areas described above have not been

explored for geothermal resources in sufficient detail to prove an absence of potential. Thus, no areas were mapped as “no potential” within the Ring of Fire planning area. Areas outside of the high-medium-low potential regions are labeled “N” on the maps, indicating “not determined” due to insufficient evidence.

Confidence Level. BLM (1985 and 1990) guidance suggests that level of confidence or certainty in the accuracy of the mineral potential interpretation be indicated through standard cartographic techniques. For the purposes of this document, confidence level is indicated on the maps by line type as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid lines. All high geothermal potential areas based on known hot springs or fumaroles fall into this category.
- Areas where direct evidence is available but is quantitatively minimal are indicated by long-dashed lines. For example, areas of the southeast region where hot springs are widely spaced, or areas interpreted based on Quaternary volcanism alone in the absence of vents or springs, fall into this category.
- Areas where indirect evidence alone supports the interpretation are indicated by short-dashed lines. For example, most areas of low geothermal potential interpreted on the basis of tectonics and structural trends fall into this category.

Summary. High and medium potential ratings were generally given to discontinuous areas described above in the Aleutians, on the Alaska Peninsula, along the west side of Cook Inlet in the southcentral region, and in the southeast region (Figures G-22 through G-25). Low potential areas generally encompass the entire Aleutian arc and in the western southcentral region, plus several isolated areas within the southeast region. Areas within the Ring of Fire planning area not exhibiting any of the above characteristics are designated as having no geothermal potential; that is, there is a demonstrated absence of geologic evidence indicating the existence of hydrothermal convection systems (BLM 1990).

3.1.5 Solid Leasables

Several varieties of solid mineral commodities are considered leasable minerals under the Mineral Leasing Act for Acquired Lands of 1947 (Nichols 1999). Examples include potassium, sodium, phosphate, and oil shale. Only one of these, phosphate, has been documented in the Ring of Fire planning area. Two occurrences are been reported by USBOM (1995) and Kline and Pinney (1994): one at an unknown site in Tuxedni Bay along the southwest side of Cook Inlet, and one in the southeast region on Snettisham Peninsula.

3.2 Locatable Minerals

As indicated in Section 1.2, locatable minerals include primarily metallic and certain nonmetallic industrial minerals generally found in lode or placer deposits. The following sections provide an overview of available information on locatable minerals within the Ring of Fire planning area, a discussion of the occurrence potential criteria used in this analysis, and a summary of locatable minerals by geographic region within the planning area.

3.2.1 Overview of Available Data

Substantial studies of mineral deposits and the mineral resource potential of Alaska have been conducted over the past few decades by the USGS, DGGS, USBOM, and BLM due to interest in exploration by private mining companies and the establishment of new parks, wildlife refuges, and Native Corporations as a result of ANCSA and ANILCA. These studies have resulted in abundant information on mineral deposits within the Ring of Fire planning area. The following provides an overview of data available that are pertinent to the understanding of locatable minerals in the Ring of Fire planning area, and which provide the basis for mapping mineral potential (Figures G-26 through G-29).

3.2.1.1 Mineral Terranes

The word “terrane” is typically used where an assemblage of related rocks occupy a certain geographic area. Mineral terrane maps were developed to depict rock assemblages that share origins and formation processes known to result in certain types of mineral deposits (Hawley and Arctic Environmental Information and Data Center [AEIDC] 1982). Mineral terranes were originally described and mapped in Alaska by USBOM in the 1970s and subsequently revised several times (e.g., AEIDC 1979; Hawley and AEIDC 1982; RDI *et al.* 1995; Szumigala 1999). The most recent electronic version of mineral terranes available (RDI *et al.* 1995; Williams and Ellefson 2004) is depicted on Figures G-26 through G-29. Mineral terrane data are unavailable for the Aleutian Chain.

Table G-3 provides a legend describing each of the terrane types on the maps. Mineral deposit types are divided into categories by formation process and rock type. Syngenetic mineral deposits form about the same time as the rocks they are encased in, while epigenetic deposits form by metamorphic or hydrothermal alteration processes following host rock deposition (AEIDC 1979). Further subdivisions of mineral terranes into rock types are based on the recognition that certain kinds of minerals are specifically associated with certain kinds of host rocks. For example, the metallic elements copper, nickel, and chromium, and the nonmetallic mineral asbestos, are typically associated with mafic igneous rocks or gabbro; while copper and zinc are typically associated with layered submarine volcanic rocks and sulfide-rich sediments, referred to as VMS deposits (AEIDC 1979; Hawley and AEIDC 1982).

3.2.1.2 Mineral Occurrences, Deposits, and Claims

There is an abundance of publicly available electronic database information that provides data on mineral occurrences within the Ring of Fire planning area. As discussed in Section 2.4.2, several online USGS databases contain geochemical analyses of stream samples that can be reviewed for anomalies indicating the potential presence of mineralized areas. At least two additional databases provide information specific to mineral occurrences and sites. BLM’s MAS/MILS database contains spatial and commodity data for mineral occurrences, deposits, mines, and processing plant sites in Alaska (USBOM 1995). An update of this database, referred to as the Alaska Minerals Information Service (AMIS) (BLM 2004b) is available at the BLM Alaska State office. USGS’ Alaska Resource Data File (ARDF) database provides locations and descriptions of mines, prospects, and mineral occurrences for metallic mineral commodities and certain high-value industrial minerals (USGS 2004a). Much of the data are based on earlier systematic listings compiled by quadrangle by USGS geologists (e.g., Cobb and Elliot 1980; Cobb and Kachadoorian 1961; Cobb and Reed 1980). Together, more than 10,000 mineral sites are listed in these databases within the Ring of Fire planning area.

Cox and Singer (1986) define “mineral occurrence” as a concentration of a mineral considered to have some value or scientific interest, and “mineral deposit” as an occurrence of sufficient size and grade that it could have economic potential. While the electronic databases list all reported occurrences and deposits regardless of economic potential, Nokleberg *et al.* (1987 and 1994) provide summaries of lode and placer deposits considered significant based on size, favorable geology, or industry interest. The location of these deposits is available electronically from ADNR (2001) and is plotted on Figures G-26 through G-29.

Mining claims are available electronically from BLM (2004c) and ADNR (2001) for those larger than one-half of a section or 320 acres in size. State and federal claims that exceed this size threshold are shown on Figures G-26 through G-29. Claim locations generally indicate the level of mineral potential known in 1971 and before, as there has been no opportunity to stake federal mining claims on most BLM lands within the Ring of Fire planning area since that time due to ANSCA and ANILCA land withdrawals (Section 1.1).

3.2.1.3 Known Mineral Deposit Areas

Known mineral deposit areas (KMDAs) were established in the southeast region during development of the Tongass National Forest (TNF) Land Management Plan in 1991, and during the mid-1990s for the rest of the Ring of Fire planning area by USBOM (RDI *et al.* 1995). KMDAs are described as a management tool for determining the likelihood of future discoveries in a particular area. They are based on a high concentration of historic mines and prospects, mineral occurrences in the MAS/MILS database, and favorable geologic trends determined by mineral terrane mapping (Maas *et al.* 1995; RDI *et al.* 1995). Bittenbender *et al.* (1999) and Still *et al.* (2002) define KMDAs as having a high concentration of mineral occurrences of a single type, which suggest an increased likelihood that the rocks host significant mineral deposits compared to other areas. The most recent version of KMDAs is electronically available (RDI *et al.*, 1995) and is depicted on Figures G-26 through G-29. In some areas of the Ring of Fire planning area, more recent BLM or USGS have resulted in revisions of KMDA boundaries investigations (e.g., Bittenbender *et al.* 1999; Nelson and Miller 2000; Still *et al.* 2002).

3.2.1.4 Mineral Resource Reports

A number of investigations specific to mining districts and specific deposit localities have been conducted by AEIDC, the former USBOM, BLM, DGGS, and USGS over the past few decades. In the early 1970s, AEIDC mapped and described mineral deposits, metalliferous provinces, and mining activity throughout the State (e.g., Selkregg 1974a). USBOM conducted numerous field investigations at specific mineral localities within the Ring of Fire planning area (e.g., Foley 1989; Kurtak 1982). Mineral potential was analyzed on several land parcels within the Ring of Fire planning area as part of the state-selection process (e.g., DGGS 1993b). Mineral potential was mapped in the TNF in the early 1990s as part of the TNF Land Management Plan (USFS 1997). BLM is responsible for conducting mineral assessments on public land in Alaska as authorized by ANILCA. Their primary focus within the Ring of Fire planning area has been on conducting investigations within five regional mining districts: PWS/Hope, Juneau, Chichagof, Petersburg/Kupreanof, and Ketchikan/Hyder (BLM 2004a). Most lands in these districts consist of federal mineral estate managed by the USFS, with little to no BLM-managed surface parcels.

The science of mineral prediction is based partly on classifications derived from mineral deposit models. Mineral deposit models describe the essential attributes of different classes of deposits, including the origin of the mineral-hosting rocks and their relationship to the commodity types found. Such models have been developed for numerous mineral types by the USGS and other researchers (e.g., Cox and Singer 1986; Orris and Bliss 1991; Mosier and Bliss 1992), and have been refined and expanded for Alaska-specific lode and placer deposits by Nokleberg *et al.* (1987 and 1994).

For over 20 years, DGGS has produced a series of annual reports and other documents on the status of exploration, development, and production in Alaska's mining industry (e.g., Bundtzen *et al.* 1982; Szumigala *et al.* 2002). Mineral resources and mining activity are described for national forests and wildlife refuges within the Ring of Fire planning area by USFS (1997 and 2000) and USFWS (1985, 1987, and 1988). A summary of pertinent information from the above reports is presented on a geographic basis in Section 3.2.3.

3.2.1.5 Strategic and Critical Minerals

Certain mineral commodities have been termed "strategic" or "critical" by the U.S. government. Strategic minerals are those that are essential to national defense, for which we are mostly dependent on foreign sources for during war, and for which strict measures controlling conservation and distribution are necessary. Critical minerals are also essential to national defense, but their procurement during war is less serious because they are either produced domestically or can be obtained through more reliable foreign sources (Thrush 1968).

Bundtzen *et al.* (1980 and 1982) summarize significant sources and reserves of strategic and critical minerals in Alaska. In addition, the MAS/MILS database was initially developed as a systematic assessment of strategic and critical minerals. Of 17 strategic minerals, 10 have been identified within the Ring of Fire planning area, including cobalt, chromium, fluorine, manganese, nickel, niobium, optical mica, platinum group metals (PGE), tantalum, and tungsten. With the exception of chromium, manganese, and tungsten, these minerals have only been identified in mineral deposits of the southeast region. Chromium, manganese, and tungsten are also found at several southcentral region locations (Bundtzen *et al.* 1980 and 1982; Kurtak 1982).

Reserves of certain critical minerals, such as barite, gold, gypsum, silver, titanium, and zinc, also occur in the southeast region (Bundtzen *et al.* 1980), as well as gold, gypsum, silver, and zinc in the southcentral region (Bundtzen *et al.* 1980; Nelson and Miller 2000). Nokleberg *et al.* (1987) suggest reserves of gold, silver, and zinc may be present on the Alaska Peninsula and eastern Aleutians.

3.2.2 Occurrence Potential

The occurrence potential for locatable mineral resources within the Ring of Fire planning area is summarized on Figures G-26 through G-29. Criteria for this mapping effort were developed by URS and BLM geologists in accordance with pertinent BLM guidance (BLM 1985; Persson 2004). The maps show potential locatable mineral resource areas for all commodities combined, and without regard to land status.

Potential Ratings. Occurrence potential ratings for locatable minerals are based on the following rationale:

<u>High Locatable Minerals Potential</u>: BLM (1985) guidance suggests that areas of high mineral potential be demonstrated based on geologic environment, inferred geologic processes,

reported mineral occurrences, valid geochemical/geophysical anomalies, and known mines or deposits. Within the Ring of Fire planning area, areas were mapped as high potential where existing state and federal mining claims indicate industry interest in a region or locality, where significant lode deposits have been documented (ADNR 2001; Nokleberg *et al.*, 1987), and/or where specific investigations have previously identified high potential areas (Bittenbender *et al.* 1999; DGGS 1993b; Maas *et al.* 1995; Nelson and Miller 2000; Still *et al.* 2002; USFS 1997).

<u>Medium Locatable Minerals Potential</u>: Areas mapped as medium potential include mineral terranes, placer mining districts, and KMDAs not specifically mapped as high potential by previous authors. The medium potential category also encompasses nearly all of the mineral locations and occurrences identified in the MAS/MILS and ARDF databases.

<u>Low Locatable Mineral Potential</u>: Most areas outside of the medium and high potential boundaries were interpreted to have low potential for locatable mineral occurrence. No areas of the Ring of Fire planning area were considered to have “no” potential, because all geologic units have some measure of mineral potential.

<u>Not Determined</u>: In several areas of the Ring of Fire planning area, locatable mineral potential cannot be determined due to lack of data, for example, beneath ice-cover of the southcentral and southeast regions. These areas are labeled “N” for not determined.

Confidence Level. Level of certainty in the data is indicated on the maps by line type as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid lines. This was considered to be the case for all mineralized areas identified as high potential with the exception of the Aleutians.
- Areas where direct evidence is available, but is quantitatively less, are indicated by long-dashed lines. Most areas of medium potential and two areas of high potential in the Aleutians fall into this category.
- Areas where indirect evidence alone supports the interpretation are indicated by short-dashed lines. Most areas of the Aleutians fall into this category, that is, mineral terrane mapping has not been conducted, and mineral potential is based on database listings alone.
- Areas where data are insufficient are indicated by dotted lines, for example, in high elevation regions and ice-covered areas of the Chugach Mountains and the southeast region.

3.2.3 Summary of Deposits and Production by Region

3.2.3.1 Alaska Peninsula/Aleutian Chain Region

Aleutian Chain. Mineral terrane information is generally unavailable for the Aleutian Chain. As such, mineral occurrence potential for the Aleutians is based primarily on MAS/MILS and ARDF occurrences, and is considered to have a lower level of certainty than the rest of the Ring of Fire planning area (Figure G-26).

USBOM (1995), USGS (2004a), and Cobb (1980) document several occurrences of copper and lead on Attu Island; gold, copper, lead, and zinc on Adak Island; and copper on Salt Island near Atka. ADNR (2001) identifies significant deposits of gold and silver on Umnak and Unalaska Islands based on ADRF data. These are located in the Geyser Bight and Makushin geothermal areas (Section 2.1.4), and are likely related to hydrothermal alteration of volcanic deposits (Berger and Singer 1992). Bundtzen *et al.* (1982) report exploration of caldera-hosted lode deposits in the Aleutians in the 1980s. Sedanka Island, located off the southwest corner of Unalaska, contains a significant polymetallic vein deposit containing base-metal sulfides of zinc, lead, and copper, which intrude a fault zone in Tertiary diorite (Nokleberg *et al.* 1987 and 1992). The nonmetallic mineral zeolite has also been reported on Unalaska.

Alaska Peninsula. Much of the Alaska Peninsula is classified as having medium potential for occurrence of locatable minerals based on mineral terrane maps, with the exception of several localized areas classified as high based on documentation of significant deposits (Figure G-27). Significant mineral deposits of the Alaska Peninsula are generally classified as one of three model types: 1) polymetallic vein deposits, 2) epithermal vein deposits, or 3) porphyry deposits. Polymetallic vein deposits generally consist of quartz-carbonate veins related to intrusions into sedimentary and metamorphic terranes, or to fluids forming during waning regional metamorphism. The veins typically contain base-metal sulfides, silver, and gold. Examples include shallow emplacement of andesitic stocks into sedimentary rocks, and disseminated sulfides in joints and veins of igneous rocks, both of which occur in the Chignik area (Nokleberg *et al.* 1987).

Epithermal vein deposits of the Alaska Peninsula are generally hosted in felsic to intermediate volcanic rocks. Notable examples include the Shumagin, Aquila, and Apollo-Sitka deposits near Sand Point that contain gold and silver in quartz veins within volcanic rocks. Reserves of gold and silver at the Shumagin prospect are estimated at about 600,000 tons of ore (Nokleberg *et al.* 1987; Szumigala *et al.* 2002). The Apollo-Sitka mine on Unga Island produced about 108,000 ounces of gold in the early 20th century, and inferred reserves are estimated at 748,000 tons. The underground workings at Apollo were reportedly reopened in the early 1980s; however, no recent production activity has been documented (Bundtzen *et al.* 1982; Szumigala *et al.* 2002). The Apollo Mine is currently the only actively held state claim on the Alaska Peninsula; there are no current federal claims in this region.

Porphyry mineral deposits on the Alaska Peninsula generally consist of stockwork veinlets in or near porphyritic intermediate to felsic intrusions. Examples include the Rex, Mike, and Bee Creek deposits of central Alaska Peninsula, which contain copper and/or molybdenum in andesitic stocks and dike swarms that intrude sedimentary and volcanic rocks. Grade estimates for these and other porphyry deposits of the Alaska Peninsula range from 0.3 to 0.7 percent copper, and 0.030 to 0.035 percent molybdenum. The Pyramid porphyry deposit near Herendeen Bay is estimated to have inferred reserves of 125 million tons of ore.

Several nonmetallic industrial minerals may also be present on the Alaska Peninsula. USFWS (1985) reports sublimation deposits of sulphur near volcanic fumaroles. Uranium may occur on the peninsula in association with sedimentary and volcanic terranes, although geiger counter surveys in the 1970s did not show significant readings. Zeolite and bentonite are probably present in association with volcanic ash (USFWS 1985).

3.2.3.2 Kodiak Region

Like the Aleutian Chain, the Kodiak region has been less explored than other areas of the Ring of Fire planning area. Mineral terranes depicted on Figure G-27 encompass a number of chromium, gold, silver, copper, and lead occurrences reported in the MAS/MILS database. With the exception of several state mining claims and one chromite deposit noted below, these areas are mapped as medium potential with respect to locatable minerals.

Selkregg (1974a) identifies a 10-mile wide swath along the northwest coast of Kodiak Island as a regional mineralized province potentially containing chromium and copper. This area corresponds to Peninsular terrane rocks extending along the Border Ranges fault zone (Sections 2.2.2 and 2.3.2). Nokleberg *et al.* (1992) and USFWS (1987) identify a significant deposit of podiform chromite within these rocks in the Kodiak National Wildlife Refuge (NWR) in the southwest corner of the island. The deposit contains an estimated 200,000 tons of ore. Podiform chromite deposits typically form as pod-like masses in the ultramafic parts of ophiolite complexes. Ultramafic rocks have been mapped in a narrow linear zone along Kodiak's northwest coast (Figure G-7).

Placer deposits of gold and other heavy minerals occur along the western beaches and have been mined on a small scale (Noklberg *et al.* 1987; Selkregg 1974a). Placer gold claims are also located in the Trinity Islands at the south end of the Kodiak region. Lode gold prospects occurring mainly in quartz veins occur throughout the island and have been sporadically explored. Minor production of lode gold has been reported from the Uyak Bay area on the west side of Kodiak. Lode occurrences of other commodities such as copper, silver, lead, zinc, and tungsten have also been reported throughout the island (Selkregg 1974a; USBOM 1995; USGS, 2004a).

3.2.3.3 Southcentral Region

The southcentral region is traversed by several mineralized regions and historical mining districts, as described in the following paragraphs.

West Side of Cook Inlet. KMDAs and mineral terranes along the west side of Lower Cook Inlet (Figure G-28) are characterized by reported occurrences of copper, gold, iron, lead, molybdenum, silver, and zinc (USBOM 1995; Selkregg 1974a; USGS 2004a). Although outside of the Ring of Fire planning area, the large Pebble copper-gold porphyry deposit on the north side of Illiamna Lake just west of the Ring of Fire planning area boundary (e.g., Alaska Department of Community, Commerce and Economic Development 2004) provides an indication of the type of deposits that may occur in association with intrusive rocks along the northern Aleutian and Alaska Ranges. Nokleberg *et al.* (1987 and 1994) identify a significant prospect of gold, silver, zinc, copper, and lead in an epithermal vein deposit hosted in volcanic rocks on the northeast side of Illiamna volcano near Tuxedni Bay. Estimated reserves are 1,100,000 tons of ore (Szumigala *et al.* 2002). Referred to as the Johnson River prospect, this deposit is currently being reevaluated for possible development (Kraus 2004).

A number of mineral occurrences of lead, zinc, silver, copper, and molybdenum have been reported in the Alaska range northwest of Mount Spurr where a KMDA has been mapped by RDI *et al.* (1995). On the western flank of Mount Spurr, DGGS (1993b) mapped a copper-molybdenum porphyry deposit as having high mineral potential based on probabilistic modeling. Nokleberg *et al.* (1987 and 1992) identify a significant porphyry molybdenum deposit in the Hayes Glacier area north of Mount Spurr, which occurs in quartz veins intruded into Tertiary granitic rocks. A number of state mining claims are concentrated in the Rainy Pass area in the northwest corner of the Ring of Fire planning area, indicating recent exploration interest in an area of Tertiary-Cretaceous intrusive rocks (Kraus 2004).

Yentna-Petersville Area. The Yentna placer district is located in the north-central part of the southcentral region. This area contains numerous state mining claims and several federal claims (Figure G-28). Total placer gold production from this area over the years has been on the order of 200,000 ounces. Recent production is reported from small placer operations (Szumigala *et al.* 2002). A recent discovery of lode diamonds was reported in the Shulin Lake area at the southern end of the Yentna district about 30 miles west of Talkeetna. The deposit is thought to represent the crater facies of a volcanic pipe-like structure within interbedded volcaniclastic and tuffaceous rocks (Szumigala *et al.* 2002).

Talkeetna Mountains. Selkregg (1974a) reports a mineralized area with potential copper deposits in the northern Talkeetna Mountains. Mineral occurrences of cobalt, gold, lead, molybdenum, silver, and zinc are also reported in this area (USBOM 1995; USGS 2004a). Several state claims are located in this area.

The Hatcher Pass-Willow Creek mining district extends from the southern Talkeetna mountains north of Palmer, towards the northeast corner of the Ring of Fire planning area. Nokleberg *et al.* (1987 and 1992) describe the lode gold deposits of the Hatcher Pass area as polymetallic quartz veins hosted primarily in granitic rocks. Total gold production in the area has been on the order of 600,000 ounces from lode gold and 60,000 ounces from placer deposits (Szumigala *et al.* 2002). Most development and production in the area took place between 1909 and 1950 (Nokleberg *et al* 1987 and 1992.). A number of state and federal claims are currently located in this area (Figure G-28), and some recent production is reported from small placer operations. Mineral occurrences of copper, mercury, molybdenum, silver, tungsten, and zinc are also reported in this district, as well as occurrences of the nonmetallic mineral talc (USBOM 1995; USGS 2004a).

Chugach and Kenai Mountains. Selkregg (1974a) identifies a metalliferous province along western front of the Chugach and Kenai Mountains extending from Homer to Palmer. Chromium and copper are the primary commodities in these Peninsular terrane rocks, which are similar to those along the northwest coast of Kodiak Island. Nokleberg *et al.* (1987 and 1992) report significant deposits and reserves of podiform chromite related to mafic-ultramafic rocks and placer deposits on the southwest coast of Kamishak Bay, with chromite contents in ore ranging as high as 43 percent. One of these two deposits, Red Mountain, produced about 29,000 tons of ore in the 1940s and 1950s. Chromite-bearing ultramafic rocks have also been reported in the Eklutna area of the Chugach Mountains north of Anchorage (Rose 1966).

A number of significant gold quartz vein deposits intrude Cretaceous metasedimentary rocks of the Chugach terrane in the Kenai and Chugach Mountains. These deposits, also referred to as Chugach-type low-sulfide gold-quartz veins, extend from the southern end of the Kenai Peninsula to the northwest and northeast corners of PWS (Figure G-28). Past production from each of these sites ranges from 2,000 to 52,000 ounces of gold (Nokleberg *et al* 1987.). The Hope-Girdwood area is also a significant placer mining district, with total production since the early 1900s of about 67,000 ounces gold and lesser amounts of silver. Recent production is reported from small placer mines in Girdwood and Hope area (Szumigala *et al.* 2002). Mineral potential has recently been mapped Chugach National Forest (CNF) by Nelson and Miller (2000). Several areas identified as being highly favorable for undiscovered Chugach-type vein gold and placer deposits were mapped as high potential on Figure G-28.

Nelson and Miller (2000) describe several VMS deposits, also referred to as Cyprus-type massive sulfide deposits, in Ghost Rocks and PWS terrane rocks of the western and northern margins of PWS (Sections 2.2.3 and 2.3.3). Deposits of this type are found in ophiolite assemblages containing pillow basalt, gabbro, sheeted dikes, and deep-water sedimentary rocks, and are favorable for concentrations of copper, lead, zinc, gold, and silver. Deposits rated highly favorable for future development were mapped on Knight and Latouche Islands in southwestern PWS.

Cook Inlet-Susitna Basin. The identification of Cook Inlet-Susitna Basin sedimentary deposits as a mineral terrane was primarily intended by AEIDC (1979) and Hawley and AEIDC (1982) to indicate the potential for coal, which is not considered a locatable mineral (Section 3.1.2). However, this terrane is included on Figure G-28 due to the potential presence of placer deposits, uranium, or other locatable minerals associated with sedimentary deposits. Several authors (Hawkins 1973; Kline and Pinney 1994; Rutledge *et al.* 1953) indicate the presence of gypsum and sedimentary zeolite deposits in upper Matanuska Valley, and diatomite on the Kenai Peninsula near Nikiski.

3.2.3.4 Southeast Region

The southeast region has a long history of mineral prospecting and mining. Mining districts of the southeast region are described in the following paragraphs generally from northwest to southeast. Much of this region is comprised of federal lands that are not actively managed by BLM for locatable minerals, such as USFS and NPS lands. Because the Ring of Fire PRMP/FEIS addresses federal mineral estate as well as BLM-managed surface lands, however, these areas are included in the following sections. This discussion is intended to be an overview, with more emphasis placed on areas with known BLM-managed lands.

Metallic Minerals – Northern Southeast Region

Yakutat Area. Gold and other heavy minerals such as titanium, platinum, and ilmenite (iron) have been found in beach sands along the northwest coast of the southeast region from Yakutat Bay to La Perouse Glacier near Icy Point (Nokleberg *et al.* 1987 and 1992). A total of about 2,000 ounces of gold have been mined from these placer deposits (Szumigala *et al.* 2002). Several offshore prospecting claims are located just south of Yakutat Bay (Figure G-29).

KMDAs related to mafic and ultramafic intrusive rocks of the Chugach terrane are located in the northeastern and southern parts of Yakutat area. A significant deposit of gabbroic nickel and copper occurs within these type of rocks at Brady Glacier in western Glacier Bay National Park and Preserve.

Glacier Bay to Skagway. Mineral resources of the Glacier Bay area have been investigated in detail by Still (1988). Based on these results, a large KMDA was identified surrounding Glacier Bay (RDI *et al.* 1995), which encircles numerous occurrences of copper, gold, molybdenum, silver, tungsten, and zinc (USBOM 1995; Nokleberg *et al.* 1987; USGS 2004a). The Glacier Bay area contains several different mineral deposit types that occur within Alexander terrane rocks, including VMS deposits, porphyry copper-molybdenum deposits, and polymetallic and gold-quartz vein deposits (Nokleberg *et al.* 1987; Szumigala *et al.* 2002).

Mineral resources of the Haines-Klukwan-Porcupine subarea of the Juneau Mining District have been investigated in detail by USBOM (1988), DGGS (1993b), and others. A number of overlapping mineral deposit types were mapped west of Klukwan along the Klehini River valley, extending southwesterly to Mount Henry Clay. The mineral deposits described in this area include: 1) stratiform VMS deposits containing bedded barite and associated lead, zinc, copper, and gold; 2) zoned mafic-ultramafic plutons intruding older Alexander terrane rocks, which contain significant lode and placer deposits of iron, titanium, vanadium, and nickel; 3) copper-gold and lead-zinc bearing skarn deposits; 4) placer gold and other heavy minerals in the Porcupine Creek area; and 5) granitic gold vein deposits throughout the area (USBOM 1988; DGGS, 1993b; Nokleberg *et al.* 1987; Szumigala *et al.* 2002). DGGS (1993b) rate the ultramafic and skarn deposits, and parts of the VMS and vein gold deposits, as having high mineral potential. Identified resources in the area include an estimated three million tons of gold ore (at 0.008 ounces/ton), 750 billion tons of zinc and silver ore (at 1.73 percent zinc and 1.75 ounces/ton silver), and 990 billion tons of soluble iron (at 10.8 to 16.8 percent) (USBOM 1988). The Porcupine placer deposits have produced a total of about 80,000 ounces of gold since their discovery, and are currently still actively producing at Big Nugget Mine (Szumigala *et al.* 2002). Approximately 555,000 cubic yards of placer gold deposits (at >0.005 ounces/cubic yard) are estimated to remain in the area. A number of current federal and state mining claims are held in the Klukwan area (Figure G-29). Relatively large parcels of BLM-managed State-selected lands are located to the north and south of Klukwan (Figure G-5).

Mineralized terrane in the Skagway area is related to Cretaceous intrusive rocks. Several occurrences of uranium, gold, silver, and copper are reported in this area (USBOM 1995; Clough 1988; USGS 2004a). Two areas of the Juneau Mining District, located northwest of Skagway and east of Haines, are largely unexplored and partly under glaciers (Gehrels and Berg 1992; RDI *et al.* 1995).

Metallic Minerals – Central and Southern Southeast Region

Most of the central and southern areas of the southeast region consist of federal mineral estate managed by the USFS or NPS. Scattered small areas of BLM-managed state- or Native-selected lands are located near the city of Juneau; on southern Admiralty Island; near the towns of Hoonah, Kake, Wrangell, and Ketchikan; and on southern Prince of Wales Island (Figure G-5).

Juneau and Admiralty Island. Mining resources of the Juneau Gold Belt and Coast Ranges subareas of the Juneau Mining District have been investigated by Redman *et al.* (1988) and Clough (1988). Significant lode deposits of the Juneau and Admiralty Island areas generally fall into one of four categories: 1) gold-quartz veins occurring in a belt along the east side of Lynn Canal and Stephens Passage (e.g., Kensington Mine) that were formed by hydrothermal fluids migrating along the Coast Ranges meagalineament and related fractures during regional metamorphism; 2) VMS deposits in volcanic rocks on northern Admiralty Island with significant reserves of zinc, lead, copper, silver, and gold (e.g., Greens Creek Mine); 3) massive sulfide deposits in metasedimentary rocks along the upper reaches of the Coast or Boundary Ranges; and 4) gabbroic nickel-copper deposits intruding Alexander terrane metamorphic rocks at the north end of Admiralty Island (Clough 1988; Nokleberg *et al.* 1987 and 1992; Redman *et al.* 1988).

Numerous federal and state mining claims are active in this area. Greens Creek is the largest producing mine in the southeast region, milling on the order of 500,000 to 700,000 tons of ore per year for the past several years (Szumigala *et al.* 2002). Kensington Mine, probably the largest deposit in the Juneau Gold Belt, produced 10,900 tons of ore prior to 1930, and is estimated to have about 11 million tons of ore remaining at 0.16 ounces/ton gold (Szumigala *et* *al.* 2002). Placer gold was discovered in the Juneau area in the 1800s. Total placer gold production in this area has been on the order of 80,000 ounces.

Chichagof and Baranof Islands. The mineral resources of Chichagof and Baranof Islands in the west-central part of the southeast region have been recently investigated by Bittenbender *et al.* (1999). Five types of mineral deposits are found on these islands: 1) gabbroic nickel-copper deposits within Chugach terrane rocks on Baranof Island and along the west coast of Chichagof; 2) gold quartz vein deposits that cross-cut Mesozoic graywacke and diorite mostly within Wrangellia terrane of western Chichagof; 3) porphyry copper-molybdenum deposits; 4) VMS deposits mostly within Chugach terrane rocks; and 5) skarn deposits on the east coast of Chichagof within Alexander terrane rocks. Two of the vein gold deposits and one of the porphyry deposits were identified as having relatively high development potential by Bittenbender *et al.* (1999). Active claims are currently held in three vein gold areas on these islands (Figure G-29).

Stikine Area. The Stikine area (Petersburg and Kupreanof Mining District) includes Kuiu, Kupreanof, Mitkof, Zarembo, Woronofski, Etolin and Wrangell Islands, as well as the mainland east of these islands. Still *et al.* (2002) recently mapped and refined the KMDAs for this area, and identified several of them as having high Mineral Exploration Potential (MEP). The deposits on these islands include: 1) VMS deposits that extend from northeast Kuiu Island, through the Duncan Canal area and central Zarembo Island, that are rich primarily in zinc and lead but locally include copper, gold, and silver; and 2) a mixture of polymetallic vein, porphyry, skarn, and vein gold deposits in the Groundhog-Berg basin area east of Eastern Passage, that are related to granitic sills and dikes intruding metamorphic rocks. Active state and federal claims are located in these areas, most notably on Woewodski Island in southern Duncan Canal (Figure G-29).

Ketchikan and Hyder District. Maas *et al.* (1995) mapped the mineral resources of the Ketchikan Mining District, which includes Prince of Wales Island, Revillagigedo Island, and the mainland area surrounding Revillagigedo. Several locations within this district were mapped as high potential on Figure G-29 on the basis of a high rating by Maas *et al.* (1995) as well as existing claims in the area. These include a number of different mineral deposit types: 1) VMS deposits in southeast and west-central Prince of Wales; 2) copper-iron skarn deposits related to granitic intrusions into limestone and calcium-rich volcanic rocks on Kasaan Peninsula; 3) polymetallic vein and small vein gold deposits in the Hyder area, Helm Bay, and central and southeast Prince of Wales; 4) porphyry copper-molybdenum deposits on southeast Prince of Wales and east of Behm Canal (e.g., Quartz Hill molybdenum deposit in Misty Fiords National Monument); 5) mafic-ultramafic deposits on the north side of Cleveland Peninsula, Salt Chuck Bay, and Duke Island; and (6) granitic ring-dike swarms rich in uranium and rare-earth elements (REE) (e.g., Bokan Mountain mine, southeast Prince of Wales).

<u>Nonmetallic Industrial Minerals</u>

Several varieties of nonmetallic industrial minerals are located in the southeast region. These include: 1) gypsum deposits on eastern Chichagof Island that are hosted in limestone skarn deposits (Bittenbender *et al.* 1999; Bundtzen *et al.* 1982); 2) asbestos occurrences in schist and gneiss rocks of the Stikine area, at the north end of Admiralty Island, and on Annette Island (Kline and Pinney 1994; Still *et al.* 2002); 3) gemstones such as garnet and zirconium; 4) an occurrence of graphite in the Stikine area (USBOM 1995); 5) fluorite in the Wrangell area (Kline and Pinney 1994); 6) mica on Sitklan Island near the southern Canadian border; 7) wollastonite on southern Prince of Wales; 8) numerous outcrops of high purity limestones; and 9) barite deposits located throughout the southeast region.

Limestones of chemical or metallurgical grade, or that are suitable for making cement (generally greater than about 96 percent calcium carbonate), are considered locatable under mining law (43 CFR 3830.12; Warfield 1962). There are a number of occurrences of limestone and marble with high purity throughout the southeast region, particularly on Prince of Wales Island (Maas *et al.* 1995).

Barite occurrences have been reported at a number of locations: in northwest Glacier Bay area, west of Klukwan near Mount Henry Clay, on Lemesurier Island in Icy Strait, on northern Admiralty Island, on northwest Kuiu Island, in the southeastern part of Kupreanof Island near Petersburg, on southern Prince of Wales Island, and on Annette Island north of Metlakatla (BLM 1995; Bundtzen *et al.* 1982; Kline and Pinney 1994; Nokleberg *et al.* 1987 and 1994). Most of these occur within VMS deposits. The northernmost deposit near Klukwan is described as bedded barite in a massive sulfide deposit within pillow basalts, and is reported to contain 750 million tons of ore with 60–65 percent barite, along with several metallic minerals described above (USBOM 1988). The deposit near Petersburg, located on the Castle Islands in Duncan Canal, was mined in the 1960s and 1970s, producing about 850,000 tons of high-grade barite ore. It is estimated that millions of tons of barite ore remain underwater at this site (Bundtzen *et al.* 1982).

3.3 Salable Minerals

As indicated in Section 1.2, salable minerals include certain mineral materials that can be disposed of either through a contract of sale or a free-use permit, such as common varieties of construction aggregate (sand and gravel), building stone, pumice, clay, and limestone. The following sections provide a description of each of these material types and their extent within the Ring of Fire planning area, as well as a discussion of the occurrence potential criteria used in this analysis. Figures G-30 through G-33 depict the extent of geologic units that are favorable for the presence of the primary salable minerals within the Ring of Fire planning area, as well as known occurrences and extraction sites documented in the USBOM (1995) MAS/MILS database.

3.3.1 Known Deposits and Resources

3.3.1.1 Sand and Gravel Aggregate

Sand and gravel and other aggregate resources are common throughout the Ring of Fire planning area, occurring primarily in association with unconsolidated surficial deposits of fluvial, glacial, and eolian origin. Unconsolidated deposits are described in Sections 2.3.1 through 2.3.4 for each region of the Ring of Fire planning area.

Broad areas of Quaternary and late Tertiary geologic units that are favorable for the occurrence of sand and gravel are depicted in yellow on Figures G-30 through G-33. These include alluvium and glacial outwash along the north coastal plain of the Alaska Peninsula (Figure G-31); a wide variety of glaciofluvial and eolian deposits in the Anchorage Bowl, western Kenai Peninsula, and Matanuska-Susitna Valley (Figure G-32); and beach ridges of the Yakutat area in the southeast region (Figure G-33) (Beikman 1980). Outside of these broad mapped areas, additional localized sources of sand and gravel include individual stream valleys, slope deposits, and beach deposits (e.g., Maas 1988; Maas *et al.* 1995; Selkregg 1974a, 1974b and 1974c; Sherman *et al.* 1997; Still *et al.*, 2002; USFWS 1988). Other forms of aggregate besides sand and gravel include crushed rock, tailings, and cinders.

The potential for locating sand and gravel deposits within different types of surficial landforms in Alaska has been classified by Reger (1988). Surficial deposits considered to have a high potential for containing quality sand and gravel deposits include floodplains, stream terraces, beach deposits, and some glacial landforms such as outwash plains, kames, and eskers. Those with low to moderate potential include alluvial fans, moraines, sand dunes, loess, tidal flats, and slope deposits such as landslides, debris flows, and talus cones.

Sand and gravel is an important commodity in Alaska, ranking only behind oil and gas in value to the State's economy. Past production in the Ring of Fire planning area has largely been project driven, with peaks occurring during periods of military construction, discoveries of oil and gas fields in Cook Inlet, and urban growth in the Anchorage and Matanuska-Susitna Valley areas (Bundtzen *et al.* 1982). Figures G-30 through G-33 depict sand and gravel extraction sites documented by USBOM (1995), many of which are related to past road construction, where sand and gravel or crushed rock aggregate have been mined to support roads and other construction needs (ADNR 1982; Kline and Pinney 1994). Recent annual production of sand and gravel and crushed rock aggregate in the Ring of Fire planning area is reported to be on the order of 8.6 millions tons in the southcentral region, 1.1 million tons in the southeast region, and 40,000 tons for the Alaska Peninsula/Aleutian Chain and Kodiak regions combined (Szumigala *et al.* 2002). Pinney and Duenwald (2001) provide a listing of private producers of aggregate in the State of Alaska based on DGGS surveys. Thirteen companies are currently listed in the southcentral region and five in the southeast region. None are listed for the Alaska Peninsula/Aleutian Chain or Kodiak regions.

3.3.1.2 Dimension Stone, Limestone, and Marble

Dimension stone, also referred to as building stone, is natural rock material of sufficient integrity and quality that it can be quarried, cut, shaped, and finished for specific construction purposes. Examples of rock types used for building stone include granite, basalt, greenstone, limestone, marble, serpentinite, and sandstones (ASTM 2004; Pinney and Duenwald 2001).

Most past production of building stone within the Ring of Fire planning area has been from limestone and marble quarries in the southeast region. The extent of geologic units containing limestone or marble is depicted on Figures G-30 through G-33 in blue. Quarries and stone pits documented by USBOM (1995) are also depicted on these figures. The most extensive sequences of carbonate rocks in the Ring of Fire planning area belong to the Silurian Heceta Limestone and the pre-Ordovician Wales Group of metamorphic rocks in the southern southeast region (Maas *et al.* 1995). Measured reserves of high quality marble in the southeast region are estimated to be over 800 million tons. Mining of ornamental marble from Prince of Wales Island began in the early 1900s. By 1949, more than two million tons of high-grade limestone and marble and 450,000 tons of structural grade limestone had been mined from quarries on Prince of Wales and Dall Islands. The southeast region marble industry declined after World War II due to changes in building styles and exploitation of marbles in contiguous U.S. states (Bundtzen *et al.* 1982). Many of the quarries in the southeast region were also developed for use as crushed rock in making logging roads.

In addition to the limestone and marble quarries of the southeast region, several stone pits have been documented near the town of Kodiak (USFWS 1988), along Turnagain Arm, along the east and west sides of lower Cook Inlet, and in the Matanuska-Susitna Valley (USBOM 1995; Kline and Pinney 1994). These may have been used for extraction of dimension stone, as well as riprap used for bank and slope protection (ASTM 2002; Pinney and Duenwald 2001).

3.3.1.3 Pumice and Pumicite

Pumice is a vesicular pyroclastic volcanic glass, usually with a felsic or rhyolitic composition. Where large amounts of water vapor and gas are present, a finer fragmentary deposit called pumicite may result (American Geological Institute [AGI] 1974; Rutledge *et al.* 1953). Pumice and pumicite are used as lightweight aggregate in the building industry, where lighter loads and higher insulating properties are desired, and as an ingredient in portland-pozzolan cements (AGI 1974; Rutledge *et al.* 1953).

Quaternary volcanic units favorable for the occurrence of pumice and pumicite are depicted on Figures G-30 through G-33 in pink. Most of these deposits are located on the Aleutian Chain and Alaska Peninsula, far from centers of construction. Occurrences of pumice documented by USBOM (1995) are also shown on the figures as triangles. Pumice has been documented at Mount Katmai on the Alaska Peninsula and on Augustine Island in lower Cook Inlet, and is likely present at other pyroclastic volcanoes throughout the Aleutian arc (AVO 2004). Volcanic ash is also likely to be present in large amounts throughout the Aleutians, Alaska Peninsula, and Cook Inlet area. Block pumice less than 2 inches in size is considered a salable material under mining law, while pumice greater than 2 inches is considered locatable (43 CFR 3830.12). Based on the results of pumice particle size analyses at Katmai and Augustine (Dahners 1947; Rutledge *et al.* 1953), most pumice in these areas appears to be of salable, not locatable, grade. Pumice and pumicite have been mined historically from Katmai and Augustine, and shipped by barge to Anchorage for use as building blocks (Rutledge *et al.* 1953).

3.3.1.4 Other Mineral Materials

Other salable minerals documented within the Ring of Fire planning area include clay used in making bricks and ceramic products, and quartz crystals used as gemstones and in industrial applications.

Kline and Pinney (1994) and Rutledge *et al.* (1953) document the location of several clay deposits in the southcentral region. Rutledge *et al.* (1953) provide the results of chemical and physical tests for several clay and shale locations in the Alaska Railroad corridor that indicate their suitability for use in the clay products industry. Clay has historically been mined from at least two formations in the southcentral region: the Pleistocene Bootlegger Cove Clay in the Anchorage area, and alteration products of Jurassic volcanic rocks in eastern Matanuska Valley near Sheep Mountain. Clay occurrences have also been identified in the Tertiary Chickaloon and Matanuska Formations of the Matanuska Valley, the Tertiary Beluga Formation near Homer, and near Moose Pass on the Kenai Peninsula (USBOM 1995; Kline and Pinney 1995; Magoon *et al.* 1976; Rutledge *et al.* 1953).

Quartz crystals have been documented by USBOM (1995) on Unalaska Island, and likely occur in many other places throughout the Ring of Fire planning area. Quartz is a nearly ubiquitous mineral found in association with granite, rhyolite, sandstone, quartztite, gneiss, and many other rock types. Large quartz crystals are typically found near hot springs, in granite porphyries, and epithermal veins (Sorden 2002).

3.3.2 Occurrence Potential

The occurrence potential for several salable mineral types within the Ring of Fire planning area is summarized on Figures G-30 through G-33. Criteria for this mapping effort were developed by URS and BLM geologists in accordance with pertinent BLM guidance (BLM 1985; Persson 2004). The maps show potential resource areas for the three primary mineral materials described in Section 3.3.1 without regard to land status.

Potential Ratings. Occurrence potential ratings for salable minerals are based on the following rationale:

High Salable Minerals Potential: BLM (1985) guidance suggests that areas of high mineral potential be demonstrated based on geologic environment, inferred geologic processes, reported occurrences, and known quarries or deposits. Areas within the Ring of Fire planning area were considered to be high potential where known occurrences and extraction sites have been identified in the MAS/MILS database (USBOM 1995), and along road systems where aggregate resources are likely to have been previously developed (Kline and Pinney 1994).

Medium Salable Minerals Potential: Areas mapped as medium potential on the basis of geologic environment and inferred processes (BLM 1985) include geologic units or terranes favorable for the primary mineral materials addressed in Section 3.3.1.

Unknown Salable Mineral Potential: All areas outside of the medium and high potential boundaries were interpreted to have an unknown potential for salable minerals occurrence. No areas of the Ring of Fire planning area were considered to have “no” or “low” potential, because nearly all geologic units have some potential for use as mineral materials, such as crushed rock.

Confidence Level. Level of certainty in the data is indicated on the maps by line type as follows:

- Areas where abundant direct and indirect evidence support the interpretation are indicated by solid lines. This was considered to be the case for road systems identified as a high potential based on historic aggregate extraction sites (Kline and Pinney 1994).
- Areas where direct evidence is available but is quantitatively less, or where indirect evidence alone supports the interpretation, are indicated by dashed lines. Geologic units mapped as medium potential fall into this category.

Summary. High potential ratings were given to isolated road systems on several islands in the Aleutian Chain, as well as near Cold Bay and Port Moller on the Alaska Peninsula. Documented pumice sites near Chignik Lagoon and Mount Katmai on the Alaska Peninsula, and along the southwest side of Lower Cook Inlet were also given high potential ratings. Stone and aggregate extraction sites and roaded areas on northeast Kodiak Island were considered high potential, as well as all of the primary road systems and known sand and gravel sites in the southcentral region. In the southeast region, much of Prince of Wales, Kupreanof, and northern Kuiu Islands were considered high potential based on existing stone quarries, as were isolated roaded areas near many of the southeast region communities. Areas of medium potential for sand and gravel, pumice, and limestone, were mapped throughout the Ring of Fire planning area based on geologic unit associations (Figures G-30 through G-33).

4.0 MINERAL RESOURCES DEVELOPMENT POTENTIAL

The potential for future mineral resource development in the Ring of Fire planning area is partly dependant upon the location of prospective resources as described in Chapter 3, and partly upon economic factors such as price trends, access, demand, etc. An analysis of development potential requires the projection of RFD per BLM guidance (BLM 1990). RFD scenarios have been prepared by BLM geologists for the Ring of Fire planning area (BLM 2004e and 2005). These documents are provided in Attachments A and B, respectively, and incorporated into the following sections.

While development potential for leasables applies to both BLM-managed surface and split estate lands, BLM does not actively manage locatable or salable minerals on split estate lands. Thus, the description of development potential for leasables is regional in scope, while that for locatables and salables is intended to apply only to BLM-managed surface lands.

4.1 Leasable Minerals

4.1.1 Oil, Gas, and Coalbed Natural Gas

Exploration and development of oil, conventional gas, and CBNG is anticipated to occur in the southcentral region as described in the RFD developed by BLM (2004e) for the Ring of Fire planning area (Attachment A). While these fluid minerals may be present in other regions of the Ring of Fire planning area (e.g., Alaska Peninsula and northwest corner of the southeast region), they are considered uneconomic to explore and develop in these areas due to inaccessibility and past exploration history. Thus, no foreseeable actions are anticipated by BLM over the next 10 to 15 years for oil, natural gas, or CBNG outside of the southcentral region.

Based on occurrence potential, as well as past exploration, accessibility, and existing infrastructure, the RFD predicts that exploration and development of oil, conventional gas, and CBNG in the Cook Inlet Basin of the southcentral region will continue to occur over the next 10 to 15 years. Cook Inlet Basin is a maturely developed basin that has produced oil and gas since 1957. The region continues to be of interest to the oil industry. Although oil exploration and production are generally in decline, steady growth in the demand for natural gas in the southcentral region has stepped up exploration drilling for this resource in recent years. The ADNR Division of Oil and Gas leasing trends suggest that there would be about 12 lease sales over the next 10 to 15 years.

The RFD projects that exploration and development would occur within three stratigraphic plays within the Cook Inlet Basin. The Beluga-Sterling Gas and Hemlock-Tyonek Oil plays (Section 3.1.1.1) are designated as having high development potential in the RFD, while CBNG resources in Cook Inlet basin (Section 3.1.3.2) are designated as having moderate development potential. The development potential ratings are based on the available data and professional judgment; however, actual future industry activity will depend on accessibility to resources, lease stipulations, exploration and development costs, success rate of future wells, oil and gas prices, and industry return on investment. In the case of CBNG, industry activity will also depend on local acceptance of split estate land issues and produced water disposal.

The RFD does not distinguish between basin-wide activity and predicted activities on specific BLM-managed lands. It is estimated that these lands (unencumbered, State- or Native-selected, and state or private split estate) encompass less than ten percent of the total basin area. Future exploration and development activity on specific BLM-managed lands would be subject to a step-down or tiered planning document prior to leasing.

Currently producing oil and gas fields in Cook Inlet Basin with federal mineral interests include the Swanson River, Beaver Creek, Kenai, and Sterling Fields. With the exception of the Swanson River Field, production from these fields is expected to continue through the next 10 to 15 years. The Swanson River Field, located in the Kenai NWR, is projected to cease production around 2017. Gas storage is currently being considered for the Swanson River Field, whereby additional gas would be brought in from outside sources and stored in the field’s reservoirs. This proposed use is not expected to extend the life of the field, however (ADN 2005).

The RFD projects the following land usage and infrastructure related to oil, gas, and CBNG development in Cook Inlet Basin over the next 10 to 15 years:

- Based on drilling activity over the past decade, it is projected that a total of approximately 41 exploration wells and 75 production wells targeting oil and conventional gas would be drilled in Cook Inlet Basin over the next 10 to 15 years. CBNG development would likely occur in the Matanuska-Susitna Valley, and could be similar in size and extent to the existing Pioneer Unit.

- Total short-term surface disturbance from initial exploration and development activities in the basin over the next 10 to 15 years is projected to be 1,094 acres for oil and conventional gas, and 1,464 acres for CBNG. Total long-term disturbance (for example, production pads and roads) is estimated to be about 75 percent of the total short-term disturbance. These estimates account for a certain percentage of wells that would be plugged and abandoned as dry holes or subeconomic, and the land reclaimed.

- Surface disturbance for oil/gas/CBNG exploration and development would include drill pads, access roads, pipelines, and utilities. CBNG development would also include compressor stations and a water disposal facility.

- Approximately 1,000 acres of additional short-term disturbance is estimated to occur as a result of geophysical exploration over the next 10 to 15 years.

- Based on historic rates of well abandonment in the basin, the RFD projects that about 161 currently existing oil and gas wells within the Ring of Fire planning area would be plugged and abandoned over the next 10 to 15 years. This includes wells at the Swanson River field. Well abandonment includes removal of equipment and structures, as well as restoration and revegetation of well sites.

4.1.2 Coal

While coal resources are present throughout much of the Ring of Fire planning area (Section 3.1.2), they were considered by BLM to be uneconomic to explore and develop over the next 10 to 15 years due to inaccessibility and past exploration history. Thus, no foreseeable actions are anticipated over the next 10 to 15 years for coal on BLM-managed lands. Most areas with coal resources within the Ring of Fire planning area were known at the time of State-and Native-land selections and were withdrawn from federal land status. Remaining BLM-managed lands are largely scattered in areas of low to medium occurrence potential (Figures G-19 through G-21).

The economics of coal development in Alaska have been challenged by the remoteness and lack of transport infrastructure at most fields, lack of terminal/port facilities, short construction seasons, steady to declining commodity prices, supply and demand balances in Asia, ocean freight rates, and the economics of scale necessitating large generation units. After two decades of steady to declining prices, Asian contract prices for thermal coal rose in 2004, a trend that is projected to continue due to global economic growth stimulating increased electricity generation requirements (AME Research 2005; Stiles 2002).

Within the Ring of Fire planning area, coal resources that have recently received industry attention include the Beluga and Matanuska fields of the southcentral region (Figure G-20). Coal in the Chuitna district of the Beluga Field has been marketed to electric utilities, cement, and industrial users in the U.S. and Asia in past decades (U.S. Environmental Protection Agency [USEPA] 1990). Economic issues of infrastructure, remoteness, and environmental impacts have combined to make development of this field subeconomic in the past. However, there may be potential industry interest in future years, as natural gas prices rise, local gas resources decline, and coal becomes a competitive energy source in the southcentral region. Conceptual ideas of a coal-fired power plant located in the Chuitna district have been floated in the past. Such a plant is currently considered competitive for supplying power to the southcentral region and the Railbelt (Stiles 2002). Based on the lack of BLM-managed lands within this district, however, the potential for coal development over the next 10 to 15 years on BLM lands is anticipated to be low.

DGGS has rated the Wishbone Hill district of the Matanuska Field as having high coal development potential (ADNR 2005; Merritt 1986c; Merritt and Relowich 1984). There has been some recent interest in leasing of State lands in this district for processing of existing coal tailings into a synthetic fuel product. In 2005, ADNR conducted a Best Interest Finding to competitively lease a 40-acre area of the Evan Jones Mine for development of the tailings as well as other coal deposits. Usibelli Coal Mine, Inc. currently has landholdings in the Wishbone Hill district and elsewhere in the Matanuska Field (Usibelli 2004). Matanuska Electric Association (MEA) recently began discussions with Usibelli to potentially construct a coal-fired power plant in the area (MEA 2005). Should Usibelli pursue coal development for utility use or export over the next 10 to 15 years, there could be interest in adjacent or nearby BLM-managed lands. The development potential of these lands is expected to be low; however, due to their location in structurally complex areas around the perimeter of the field and likely small deposit sizes.

4.1.3 Geothermal

While geothermal resources are present throughout much of the Ring of Fire planning area (Section 3.1.4), they were considered by BLM to be uneconomic to explore and develop over the next 10 to 15 years due primarily to issues of remoteness and inaccessibility to market. Future use of geothermal energy in Alaska will likely depend on funding from USDOE in the form of grants for resource exploration and definition studies (USDOE 2004a). Thus, while some geothermal exploration activities may occur over the next 10 to 15 years, development of the resource is not anticipated.

Past prospects and localized uses of geothermal resources in the Ring of Fire planning area are described in Section 3.1.4.2. Geothermal resources that have received recent industry attention the Ring of Fire planning area include Unalaska, Akutan, and Umnak Islands in the Alaska Peninsula/Aleutian Chain region, and Mount Spurr in the southcentral region (Section 3.1.4.2, Figures G-22 and G-24). Of the Aleutian prospects, Unalaska's Makushin volcano contains the largest resource, but has not been developed due to transmission line costs (Liles 2004).

Remoteness is the biggest roadblock to development of alternative power in Alaska. The profitability of geothermal power depends on the economics of scale to provide a return on investment. Remoteness necessitates high transmission line costs; thus, a geothermal-powered generating unit would need to be large to justify development. The southcentral region and the Railbelt power grid provide the only market in the Ring of Fire planning area that could make use of such generation. The closest high temperature geothermal source to this region is the Mount Spurr volcano. As indicated in Section 3.1.4.2, investigations at Mount Spurr are in the initial phases, and additional studies will be required to define the economic potential of this resource. The most promising location identified for future exploration at Mount Spurr lies on the south flank of Crater Peak (Turner and Wescott 2004), which is not located on BLM-managed lands. Thus, the development potential for this resource on BLM lands is considered to be low.

4.2 Locatable Minerals

BLM (1985) guidance pertinent to locatable minerals indicates that whenever known, projected development or economic potential should be part of the resource assessment, to the extent that it is necessary at the level of detail required for the action. Based on the intermediate level of detail specified for the Ring of Fire planning area action, and the scattered and unknown nature of BLM-managed lands within the planning area, the following sections are intended to be a qualitative overview of economic and technical factors effecting the exploitability of the resource (Sections 4.2.1 and 4.2.2), followed by a summary of development potential by region (Section 4.2.3). The summary by region incorporates projections contained in the RFD scenario developed by BLM (2005) for locatables (Attachment B). Because BLM does not actively manage locatable mineral activities on federal mineral estate lands (Section 1.4), the summary by region is intended to apply only to BLM-managed surface tracts.

There is no possibility of development of unclaimed mineral deposits in most of the Ring of Fire planning area, unless existing land withdrawals in place since the early 1970s are removed (Section 1.1). The RFD assumes that all potentially productive areas will be open to mineral entry except those closed by law, regulation, or executive order (e.g., wild and scenic rivers, Area of Critical Environmental Concern, etc.). Further, projected acreages in the RFD are based on the assumption that land conveyances will be completed and withdrawals lifted by the year 2010, which should allow for additional exploration that, in some areas, will increase the related reserve base to make mining economically feasible.

4.2.1 Economic Factors

Demand for locatable resources, most notably gold, depends strongly on the current price of gold, and the operational and administrative costs imposed by regulation and inaccessibility. After the U.S. deregulated gold in 1971, the price increased markedly, reaching a high of more than $800/ounce in 1980, which encouraged the opening of new mines in Alaska in the 1980s. The price of gold leveled off in the range of $320 to $460 per ounce after 1980, eventually resulting in a decline in mining and exploration activities in the State. In late 2003, after several years of lackluster prices, gold rose above the $400 mark for first time in seven years (Freeman 2003; Kirkemo *et al.* 1997). Today, the gold price is over $700 per ounce.

Nelson and Miller (2000) provide an example of the effect of gold prices on development potential in the CNF. They suggest that gold prices would have to be $400 to $450 per ounce for large-scale placer or lode gold operations to be economically viable, with needed reserves far exceeding what is estimated in the Chugach. Based on this, they conclude that future production in this area of the Ring of Fire planning area would require significantly higher prices to be economic.

Accessibility is also a major factor in the economics of mineral extraction in Alaska. For example, the economic potential of a mineral deposit can be directly related to the length of road required to be built for access to market. High value minerals that can be flown out by aircraft (i.e., gold) have a significant economic advantage over base metals that need road and/or port access.

4.2.2 Industry Interest

Mineral potential was reviewed in the decades following statehood, as well as following ANCSA and ANILCA, as part of land-selection processes. Because most lands with known mineral potential were previously selected and conveyed, development of locatable minerals on remaining BLM lands within the Ring of Fire planning area is expected to be minimal over the next 10 to 15 years, except where technical or economic conditions have changed since the original assessments and land selections. Thus, investigation techniques, mining processes, and industry economics that have evolved since the 1970s have a bearing on the interpretation of development potential.

Mineral investigations conducted since the 1970s have expanded the knowledge of mineral potential within the Ring of Fire planning area. These investigations have been incorporated into the current interpretation of occurrence potential presented in Section 3.2. While gold was the primary commodity of interest prior to 1970, industry economics have evolved in the last 30 years to include an interest in base metals (copper, lead, and zinc) that are typically contained within VMS deposits. In addition, in the past two decades, low-grade disseminated gold and copper deposits have become increasingly important due to the advancement of large-scale heap-leach technologies.

Heap leaching is a process whereby large piles of crushed rock are leached with various chemical solutions that extract valuable minerals (Thiel and Smith 2003), allowing for economic recovery of lower grade deposits than is possible using standard milling techniques. Disseminated gold deposits, like those of the Pogo and Fort Knox Mines in interior Alaska, occur in the distal parts of intrusion-related quartz vein systems (Cox 1992; Logan 2002). Large intrusive bodies within the Ring of Fire planning area are located along the spine of the northern Aleutian Range, along the east side of the southern Alaska Range, in the Talkeetna Mountains, and along the Boundary Ranges of the southeast region. These trends are noted below as they relate to development potential in the Ring of Fire planning area.

4.2.3 Summary by Region

The location of known BLM-managed lands depicted on Figures G-2 through G-6 (BLM, Native-selected, and State-selected) were reviewed in relation to mineral occurrence potential outlined on Figures G-26 through G-29 and significant mineral deposits mapped by Nokleberg *et al.* (1987 and 1994) to assess development potential in specific areas of the Ring of Fire planning area. In addition, the RFD reviewed individual mineral occurrences listed in BLM (2004b) and USGS (2004a) databases to identify those that are located both within high occurrence potential boundaries and on BLM-managed lands (unencumbered, State- and Native-selected) (Attachment B, Table G-2). Mineral deposit model types identified in the RFD that are projected to be economic and receive industry attention over the next 10 to 15 years include epithermal gold and gold-quartz vein deposits, placer gold, porphyry copper, VMS deposits (copper-lead-zinc), and polymetallic vein deposits.

Alaska Peninsula/Aleutian Chain Region. Development potential in this region is generally expected to be low on BLM-managed lands over the next 10 to 15 years due to its remoteness and inaccessibility. Most of the region is underexplored compared to the rest of the Ring of Fire planning area, and there is only one current mining claim in the area, indicating low overall interest. BLM-managed lands make up a very small portion of this region as well.

Several of the significant lode deposits in this region described by Nokleberg *et al.* (1987 and 1994) and mapped as having high occurrence potential may be located partly on Native-selected land. These include Sedanka Island at the southeast corner of Unalaska, the Pyramid deposit in the Herendeen area, Bee Creek at Chignik Bay, and the Mike and Rex deposits near Mount Chiginagak. Interest in developing these prospects may increase over the next 10 to 15 years if commodity prices were to increase substantially.

The RFD identifies several mineral occurrence sites on the Alaska Peninsula containing epithermal gold-silver, porphyry copper, or lead-zinc deposits that could be explored over the next 10 to 15 years, potentially disturbing a total of up to 15 acres. Mine development on any one of these sites could occur beyond the next 10 to 15 years, potentially disturbing up to 70 acres.

Kodiak Region. BLM-managed lands on Kodiak are expected to have low development potential due to remoteness and inaccessibility, and the lack of BLM lands in areas of high occurrence potential. The areas of the Kodiak region rated as having high occurrence potential are either located within the Kodiak NWR or are based on State claims. It is possible that BLM-managed lands in beach placer areas, or in the underexplored ultramafic belt along the northwest coast, may see renewed exploration interest if commodity prices were to increase substantially. Scattered Native-selected lands are located in these areas.

Southcentral Region. The southcentral region is an area with relatively higher accessibility than other parts of the state. With a few exceptions, development potential in this region is generally considered to be 1) medium for areas of high occurrence potential, and 2) low for areas of medium occurrence potential.

Based on recent industry interest in intrusion-related disseminated gold deposits and porphyry copper-gold deposits similar to the Pebble prospect at Illiamna Lake, BLM-managed lands located on the west and south sides of Mount Spurr in an area of medium occurrence potential (Figures G-4 and G-28) may have as much as medium development potential, although overlying host rocks are sparse in this area (Figure G-8).

VMS deposits on Knight Island in western PWS, which were rated highly favorable for future development by Nelson and Miller (2000), may overlap with scattered Native-selected parcels in the area.

Several areas of State-selected lands on the Kenai Peninsula may overlap areas of high occurrence potential/medium development potential in the gold mining district extending from Girdwood and Hope to the Seward area. Small-scale placer production on the more easily accessible lands within this area is possible over the next 10 to 15 years. The RFD projects that exploration at a number of gold-quartz vein and placer gold deposits could disturb up to a total of 16 acres of land. Current and future development at an existing operation in the Girdwood area is anticipated to disturb up to an additional 15 acres over the next 10 to 15 years.

Southeast Region. Small tracts of BLM-managed lands overlap areas designated as high occurrence potential in the following areas: near Klukwan, near the city of Juneau, Hawk Inlet at the north end of Admiralty Island, near Sitka, near Hyder, and at three locations on southern Prince of Wales Island (Trocadero Bay, Billie Mountain, and Aiken Cove). With three exceptions noted below, these sites are considered to have medium development potential. Areas of medium occurrence potential in the southeast region are generally considered to have low development potential.

The State-selected tracts near Klukwan, Hawk Inlet, and Aiken Cove are considered to have medium to high development potential. The tracts near Klukwan lie along the east and south edges of a large area of VMS, placer gold, and other types of mineral deposits, with recent industry interest and many claims in the area. The Hawk Inlet tracts are adjacent to the Greens Creek VMS deposit. Aiken Cove in southeast Prince of Wales Island lies at the north end of the Niblack VMS prospect, which was rated as having high development potential by Maas *et al.* (1995).

The RFD projects that several of the placer gold, VMS, and polymetallic vein deposits in the southeast region may be explored over the next 10 to 15 years, potentially disturbing up to 18 acres. One existing inactive placer operation located in the Klukwan area on State-selected land is projected to disturb up to five acres.

4.3 Salable Minerals

BLM (1985) guidance pertinent to salable minerals indicates that whenever known, projected development or economic potential should be part of the resource assessment, to the extent that it is necessary at the level of detail required for the action. Based on the intermediate level of detail specified for the Ring of Fire planning area, and the scattered and unknown nature of BLM-managed lands within the planning area, the following is intended to be a qualitative overview of salables development potential based on projected demand.

4.3.1 Material Types and Demand

There are four types of salable minerals with a history of exploration and/or development in the Ring of Fire planning area: aggregate (sand and gravel), building stone, clay, and pumice (Section 3.3.1). The RFD for salable minerals (BLM 2005) (Attachment B) projects that there will be little or no foreseeable development potential for clay and pumice over the next 10 to 15 years due to lack of markets and great distances to markets for these materials. Thus, the summary by region below focuses on aggregate and stone.

Most aggregate development in the Ring of Fire planning area in the past has been project driven, as most lands are too remote for salable minerals to be marketable in the absence of specific projects. The assessment of development potential assumes that demand for aggregate will increase over the next 10 to 15 years as road maintenance and construction activities continue on state highways and non-BLM lands. The projection of demand within each region considers future activities external to BLM lands that may affect the need for these materials. Future external events considered in this analysis are contained in Chapter 4 of the PRMP/FEIS document, and included in the following discussion.

4.3.2 Summary by Region

There are currently no known salable mineral activities on BLM-managed lands within the Ring of Fire planning area (BLM 2005). Because demand for aggregate is expected to increase, there may be interest in aggregate on BLM-managed lands located near future projects if there are no pre-existing alternative non-BLM extraction sites available. Generally, areas with expected future projects and no existing extraction sites were considered to have medium development potential for localized sources of aggregate on BLM-managed lands. Areas with existing non-BLM extraction sites, or with no anticipated future projects, were estimated to have low development potential. No areas of high development potential (e.g., major sand and gravel deposit in an area with future projects, with no existing extraction sites nearby) were identified in the Ring of Fire planning area.

Alaska Peninsula/Aleutian Chain Region. There are no anticipated future projects in the Aleutians that could effect demand for aggregate over the next 10 to 15 years. Future projects on the Alaska Peninsula are expected to include areawide oil and gas leasing and new state road construction near Chignik. Because the development potential for oil and gas in this area is anticipated to be low over the next 10 to 15 years (Section 4.1.1), the results of the leasing program are not expected to increase demand for salables extraction. There are no major sources of sand and gravel in the Chignik area (Figure G-31); hence road construction could increase the demand for localized sources such as beach or river deposits. Localized deposits on BLM-managed lands in the Chignik area may have medium development potential.

Kodiak Region. Future projects that could effect demand for aggregate on Kodiak are expected to be limited to rehabilitation and maintenance of existing roads. As there are several existing non-BLM aggregate and stone extraction sites currently on Kodiak (Figure G-31), development of new extraction sites on BLM-managed lands is not expected to occur.

Southcentral Region. Future projects that could effect demand for aggregate in the southcentral region are expected to include: state oil and gas leasing; an access road to the proposed Pebble Mine on the west side of lower Cook Inlet (Illiamna or Iniskin Bays); State coal leasing in the Matanuska Valley; and road projects in the Anchorage Bowl and Kenai Peninsula.

Because there are currently a number of existing non-BLM sand and gravel extraction sites in the Anchorage, Matanuska-Susitna, and Kenai areas (Figure G-32), development of new extraction sites is not anticipated on BLM-managed lands in these areas. Pebble Mine road construction could increase demand for localized sources of aggregate such as beach or river deposits, as there are no major sources of sand and gravel mapped in the Illiamna-Iniskin Bay areas. Thus, there may be interest in development of new extraction sites on Native-selected lands in this area. Localized deposits on these lands may have medium development potential.

Southeast Region. Future projects that could effect demand for salable minerals in the southeast region over the next 10 to 15 years are expected to include: existing mine development (e.g., Greens Creek, Kensington); timber sales in the TNF; and state road projects in the Juneau-Skagway, Sitka, and Bradfield Canal areas. Although there are no major geologic sources of sand and gravel in these areas, there are currently a number of existing non-BLM limestone quarries and localized sand and gravel extraction sites throughout the southeast region (Figure G-33). Thus, it is anticipated that new salables extraction sites would not be developed on BLM-managed lands in this area.

5.0 RECOMMENDATIONS

Recommendations and stipulations related to the management of future mineral development in the Ring of Fire planning area were developed concurrently as part of the PRMP alternatives process, and are presented in the PRMP/FEIS document in Appendix D.

6.0 REFERENCES AND SELECTED BIBLIOGRAPHY

Anchorage Daily News (ADN). 2004a. Feds Halt Inlet Gas Lease Sale. May 19.

ADN. 2004b. Legislature OKs Bills for Bristol Bay Oil, Gas Leasing. March 17.

ADN. 2004c. Marathon Finds New Cook Inlet Gas. Published August 31. www.adn.com/business/story/5491013p-5429276c.html.

ADN. 2004d. State Sale of Leases a Success. May 20.

ADN. 2005. Plan to Store Gas in Refuge Gains Support. April 12.

Alaska Department of Natural Resources (ADNR). 1982. GIS Roads Layer: "road 2 mil."

ADNR 1991. adnr_ak_coal_deposits_alb154. Geospatial data digitized from DGGS Special Report 37. ADNR Land Records Information Section. June.

ADNR Division of Mining, Land, and Water. 2005. Final Best Interest Finding to Lease 40 Acres of the Wishbone Coal Field near Sutton, Alaska. In Response to an Application by Sutton Partners LLC (Knoll Acres Associates, LLC). May 9. 19 p.

ADNR Division of Oil & Gas. 2002. 2002 Report, Table and Graphs Edition. www.dog.dnr.state.ak.us/oil/products/maps/othermaps/othermaps.htm. December.

ADNR Division of Oil & Gas. 2003a. Cook Inlet Activity & Discoveries January 2003. Map scale 1:1,000,000. www.dog.dnr.state.ak.us/oil/. January 15.

ADNR Division of Oil & Gas. 2003b. Letter to Evergreen Resources Alaska Corp., RE: Plan of Operation LO/CI 03-17, Mat-Su Core Holes 2003. December 16.

ADNR Division of Oil & Gas. 2003c. Oil and Gas Report, for the Period Ending December 31, 2002. www.dog.dnr.state.ak.us/oil/products/publications/otherreports/otherreports.htm#2003annualreport.

ADNR Division of Oil & Gas. 2004a. Bristol Bay Region and Alaska Peninsula Oil and Gas Programs. Alaska Peninsula Oil and Gas Resource Series, Plate 1. Map scale 1:1,000,000. www.dog.dnr.state.ak.us/oil/products/maps/otherimages/AKPen_BB_Political_low_res.jpg.

ADNR Division of Oil & Gas. 2004b. Download Data, Lease Information, and Unit Boundaries. www.dog.dnr.state.ak.us/oil/products/data/downloads/downloads.htm. Updated August 9.

ADNR Division of Oil & Gas. 2004c. Letter to Evergreen Resources Alaska Corp., RE: Plan of Operation LO/CI 03-17, Mat-Su Core Holes 2003, Amend to Add Slats#1 Core Hole. April 23.

ADNR Division of Oil & Gas. 2004d. Shallow Gas. www.dog.dnr.state.ak.us/oil/programs/shallowgas/shallowgas.htm. Updated June 22.

ADNR Division of Oil & Gas. 2004e. Well Information. www.dog.dnr.state.ak.us/oil/products/data/wells/wells.htm. Updated May 28.

ADNR Division of Oil & Gas. 2004f. Unit Maps. www.dog.dnr.state.ak.us/oil/products/maps/othermaps/othermaps.htm. Updated September 8.

ADNR Division of Oil & Gas. 2005. Shallow Gas. www.dog.dnr.state.ak.us/oil/programs/shallowgas/shallowgas.htm. Updated April 8.

ADNR. 2001. General Land Status with Mineral Resources and Mining Claims. Produced by Division of Support Services, Land Records Information Section. Map scale 1:2,500,000. Version 8, October 23.

Alaska Department of Community and Economic Development (DCCED). 2004. Lake & Peninsula Borough: Economic Overview. www.dced.state.ak.us/cbd/AEIS/LakePen/General/. Accessed May 27.

Alaska Oil and Gas Conservation Commission (AOGCC). 2004. 2003 Annual Report. www.aogcc.alaska.gov/annual/2003. June 8.

Alaska Volcano Observatory (AVO). 2004. Volcano Atlas. www.avo.alaska.edu/avo4/atlas/atlas.htm. Accessed May 4.

Alstatt, A.A., R.W. Saltus, R.L. Bruhn, and P.J. Haeussler. 2002. Magnetic Susceptibilities Measured on Rocks of the Upper Cook Inlet, Alaska. U.S. Geological Survey Open-File Report 02-0139, version 1.0. http://pubs.usgs.gov/of/2002/ofr-02-0139/.

AME Research. 2005. Thermal Coal. www.ame.com.au/guest/Co. Accessed June 28.

American Geological Institute (AGI). 1974. Dictionary of Geological Terms. Anchor Books, Garden City, NY. 545 p.

Arctic Environmental Information and Data Center (AEIDC), University of Alaska. 1979. Mineral Terranes of Alaska - 1979 Series. Published by U.S. Bureau of Mines (USBOM). 6 map sheets, scale 1:1,000,000.

American Society of Testing and Materials (ASTM). 1999. Standard Classification of Coals by Rank. Document No. ASTM D388-99e1. 7 p. September 10.

ASTM. 2002. Standard Terminology Relating to Soil, Rock, and Contained Fluids. Document No. ASTM D653-02.

ASTM. 2004. Standard Terminology Related to Dimension Stone. Document No. ASTM C119-04a.

Bailey, E.A., D.B. Smith, C.C. Abston, M. Granitto, and K.A. Burleigh. 2000. National Geochemical Database: U.S. Geological Survey RASS (Rock Analysis Storage System) Geochemical Data for Alaska. U.S. Geological Survey (USGS) Open-File Report 99-433, version 2.0. http://geopubs.wr.usgs.gov/open-file/of99-433/. Last modified March 17.

Bailey, E.A., Geochemist, U.S. Geological Survey. 2004. Verbal communication, re: Geochemical databases in southern Alaska. May 14 and 19.

Barker, F., J.N. Aleinikoff, S.E. Box, B.W. Evans, G.E. Gehrels, M.D. Hill, A.J. Irving, J.S. Kelley, W.P. Leeman, J.S. Lull, W.J. Nokleberg, J.S. Pallister, B.E. Patrick, G. Plafker, C.M. Rubin. 1994. Some Accreted Volcanic Rocks of Alaska and Their Elemental Abundances, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 555-587.

Barnes, F.F. 1962. Geologic Map of Lower Matanuska Valley, Alaska. USGS Misc. Geological Investigation Map I-359. Scale 1:63,360.

Barnes, F.F. and T.G. Payne. 1959. The Wishbone Hill District, Matanuska Coal Field, Alaska. USGS 1016. 88 p., 20 plates.

Beeman, W.R., R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Beikman, H.M. 1980. Geologic Map of Alaska. USGS Special Map, scale 1:2,500,000. 2 sheets.

Belowich, M., geologist, Evergreen Resources Inc. 2003. Verbal communication, re: Conditions for CBNG occurrence in Matanuska-Susitna valley area. October 3.

Bittenbender, P.E., J.C. Still, K.N. Maas, and M.E. McDonald, Jr. 1999. Mineral Resources of the Chichagof and Baranof Islands Area, Southeast Alaska. BLM-Alaska Technical Report 19. 222 p., 3 plates. February.

Bittenbender, P.E., K.W. Bean, and J.C. Still. 2001. Stikine Airborne Geophysical Survey Follow-up, Central Southeast Alaska, 2000. BLM-Technical Report 37, BLM/AK/ST-02/002+3090+932. November. 116 p.

Bureau of Land Management (BLM). 1985. BLM Manual 3031 – Energy and Mineral Resource Assessment. Rel. 3-115. June 19.

BLM. 1990. Planning for Fluid Mineral Resources, BLM Handbook H-1624-1. Rel. 1-1583. May 7.

BLM. 2001. Plain Language, Bureau of Land Management, Geothermal Resources Proposed Regulation (43 CFR Parts 3200, 3210, 3220, 3240, 3250, 3260), Federal Register: October 8, 1996 (Volume 61, Number 196) (Excerpt). www.plainlanguage.gov/example/regs/blmreg1.htm. Accessed 5/17/04.

BLM. 2004a. Alaska Mineral Assessments, Mining District Studies. BLM Brochure BLM/AK/AE-99/013+3090+933. Revised 2004.

BLM. 2004b. Alaska Minerals Information Service (AMIS). Available at BLM Alaska State Office, Anchorage, Alaska. November.

BLM. 2004c. Electronic geospatial data showing federal and state of Alaska mining claims. Anchorage, Alaska. 1 disk. April 30.

BLM. 2004d. Explanation of “Discovery”. www.ut.blm.gov/MineralsAdjudication/Mining%20Claims/. Accessed April 23.

BLM. 2004e. Reasonable Foreseeable Development Scenario for Oil and Natural Gas Resources in the Ring of Fire Planning Area, Alaska. Draft rept. prep. by BLM Alaska State Office, Division of Energy and Solid Minerals. 73 p. December.

BLM. 2005. Draft, Ring of Fire RMP Reasonable Foreseeable Development Scenario, Locatable and Salable Minerals. Rept. prep. for BLM AFO, as part of the Ring of Fire Resource Management Plan, prep. by Staff, BLM Div. of Energy and Solid Minerals. 37 p. March, updated April 22.

Brimberry, D.L. P.S. Gardner, M.L. McCullough, and .E. Trudell. 1997. Kenai Field, the Kenai Peninsula's Largest Gas Field., in Karl, S.M., T.J. Rhyherd, and N.R. Vaughn, eds., 1997 Guide to the Geology of the Kenai Peninsula, Alaska. Alaska Geological Society, Anchorage, Alaska, 2nd printing 1999. p.28-35.

Bruns, T.R. 1996a. Gulf of Alaska, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Bruns, T.R. 1996b. Gulf of Alaska, in Gautier, D.L., G.L. Dolton, .I. Takahashi, and K.L. Varnes, eds., 1995 National Assessment of United States Oil and Gas Resources - Results, Methodology, and Supporting Data. U.S. Geological Survey Digital Data Series DDS-30, Release 2. 1 disk.

Bundtzen, T.K., G.R. Eakins, and J.T. Dillon. 1980. Strategic and Selected Critical Minerals in Alaska Summarized. DGGS Mines & Geology Bulletin, Vol. XXIX, No. 1, p. 1-8. DGGS Misc. Publication Series MP 16. March.

Bundtzen, T.K., G.R. Eakins, and J.T. Dillon. 1982. Review of Alaska's Mineral Resources, 1981-82. DGGS. 52 p. plus app.

Burk, C.A. 1965. Geology of the Alaska Peninsula – Island Arc and Continental Margin. Geological Society of America Memoir 99, 3 Parts. 250 p., map scale 1:250,000.

Burns, L., Geophysicist, DGGS. 2004. Verbal communication, re: status of DGGS aeromagnetic survey completions. May 11.

Clough, A.H. 1988. Coast Range Subarea, in U.S. Bureau of Mines (BOM), ed., Bureau of Mines Mineral Investigations in the Juneau Mining District, Alaska, 1984-1988. Special Publication by USBOM Juneau Branch, Alaskan Field Operations Center. Volume 2.- Detailed Mine, Prospect, and Mineral Occurrence Descriptions, Section E. 44 p.

Clough, J.G. 2001. Coalbed Methane - Potential Energy Source for Rural Alaska. Alaska GeoSurvey News, Vol. 5, No. 2, June. p. 1-4.

Clough, J.G., Coal Geologist, DGGS. 2004. Verbal communication, re: results of Chignik Lake water well drilling program with respect to CBNG potential. August 12.

Cobb, E.H. and B.L. Reed. 1980. Summaries of Data on and Lists of References to Metallic and Selected Nonmetallic Mineral Deposits in the Talkeetna Quadrangle, Alaska. USGS Open-field Report 80-1053. 156 p.

Cobb, E.H. and R. Kachadoorian. 1961. Index of Metallic and Nonmetallic Mineral Deposits of Alaska Compiled from Published Reports of Federal and State Agencies Through 1959. USGS Bulletin 1139.

Cobb, E.H. and R.L. Elliott. 1980. Summaries of Data on and Lists of References to Metallic and Selected Nonmetallic Mineral Deposits in the Ketchikan and Prince Rupert Quadrangles, Alaska. USGS Open-field Report 80-1053. 156 p.

Cody, B.A. 1995. Major Federal Land Management Agencies: Management of Our Nation's Lands and Resources. Congressional Research Service Report 95-599 ENR. 35 p. May 15. www.ncseonline.org/NLE/CRSreports/Natural/nrgen-3.cfm.

Cox, D.P. 1992. Descriptive Model of Distal Disseminated Ag-Au, in Mosier, D.L. and J.D. Bliss, eds., Developments in Mineral Deposit Modeling (1992). USGS Bulletin 2004. Deposit model 19c. http://pubs.usgs.gov/bul/b2004/html/bull2004distal_disseminated_agau.htm

Cox, D.P. and D.A. Singer, eds. 1986. Mineral Deposit Models. USGS Bulletin 1693, 3rd printing 1992. 349 p.

Dahners, L.A. 1947. Preliminary Reports on Some Pumice Deposits, Augustine Island, Alaska. Alaska Territorial Department of Mines, Mineral Investigation 103-1, 22 p.

Alaska Division of Geological & Geophysical Surveys (DGGS), ADNR. 1986. Engineering Geology Technical Feasibility Study, Makushin Geothermal Power Project, Unalaska, Alaska. Report submitted to Alaska Power Authority, DGGS Public-Data file 86-60. 2 vol.

DGGS, ADNR. 1993a. Alaska's High-Rank Coals. DGGS Information Circular 33, revised ed. 36 p.

DGGS, ADNR. 1993b. Estimated Mineral Potential of Lands Available for State Selection 1991-1993. 181 p. June.

DGGS, ADNR. 2003. Coalbed Methane for Rural Alaska Energy. wwwdggs.dnr.state.ak.us/Briefing03/FY03_cbm.pdf. 1 p. Accessed August 12, 2004.

DGGS, ADNR. 2004. Geophysical Releases. http://wwwdggs.dnr.state.ak/geophys.html. Accessed May 11.

Diel, W., Geologist, BLM Alaska State Office. 2004. Verbal Communication, re: criteria for mapping occurrence and development potential for oil and gas, coal, CBNG, and geothermal resources in Ring of Fire; and status of KGRAs in Alaska. April 26 and June 2.

Dolan, T.G. 2002. Anchorage Looking for New Gas Source, in Explorer January 2002, American Association of Petroleum Geologists online newsletter. www.aapg.org/explorer/2002/01jan/alaska_cbmeth.html.

Dusel-Bacon, C. 1994. Map and Table Showing Metamorphic Rocks of Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plates 4a and 4b.

Duval, J.S. 2001. Aerial Gamma-Ray Surveys in Alaska. USGS Open-File Report 01-128, version 1.0. http://pubs.usgs.gov/of/of01-128/.

Ehm, A. 1983. Oil and Gas Basins Map of Alaska. DGGS, Special Report 32. www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=2631. 1 map sheet, scale 1:2,500,000.

ENSR Corporation and Booz Allen & Hamilton, Inc. 2003. Mineral Occurrence and Development Potential Report, Rawlins Resource Management Plan Planning Area. Prep for BLM, Rawlins Field Office, Wyoming. February.

Evergreen Resources Alaska Corporation. 2003a. Lease Plan of Operations, Mineral Core Drilling Program, Matanuska-Susitna Borough, Alaska. 30 p.

Evergreen Resources, Inc. 2003b. Operations: In Alaska. www.evergreen-res.com/finalhtmlpages/operations.html. Accessed August 4, 2004.

Fisher, M.A. 1996. Kodiak Islands, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. U.S. Geological Survey Digital Data Series DDS-35. 1 disk.

Foley, J.Y. 1989. Snipe Bay Copper-Nickel-Cobalt Deposits. USBOM Field Report. December.

Gehrels, G.E. and H.C. Berg. 1992. Geologic Map of Southeastern Alaska. USGS Misc. Investigations Series Map I-1867, Scale 1:600,000, 24 p.

Gehrels, G.E. and H.C. Berg. 1994. Geology of Southeastern Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 451-467.

Godson, R.H. 1991. Composite Magnetic Anomaly Map of Alaska and Adjacent Offshore Areas, in G. Plafker and H.C. Berg, eds., 1994, The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plate 10, scale 1:2,500,000.

Godson, R.H., ed. 1984. Composite Magnetic Anomaly Map of the United States, Part B: Alaska and Hawaii. USGS Geophysical Investigations Map GP-954-B. Scale 1:2,500,000.

Grossman, J.N. 1998. National Geochemical Atlas: The Geochemical Landscape of the Coterminous United States Derived from Stream Sediment and Other Soil Sample Media Analyzed by the National Uranium Resource Evaluation (NURE) Program (Version 3.01). U.S. Geological Survey 98-622. 26 p. plus CD.

Haeussler, P.J., R.L. Bruhn, and T. Pratt. 2000. Potential Seismic Hazards and Tectonics of the Upper Cook Inlet Basin, Alaska, Based on Analysis of Pliocene and Younger Deformation. Geological Society of America Bulletin, v. 112, no. 9, p. 1414-1429. September.

Hawkins, D.B. 1973. Sedimentary Zeolite Deposits of the Upper Matanuska Valley, Alaska. 1 map sheet.

Hawley, C.C and Associates (Hawley) and AEIDC, University of Alaska. 1982. Mineral Terranes of Alaska; 1982. Published by USBOM and DGGS. 6 map sheets, scale 1:1,000,000.

Hoover, D.B., D.P. Klein, and D.C. Campbell. 1995. Geophysical Methods in Exploration and Mineral Environmental Investigation, in Du Bray, E.A., ed., Preliminary Compilation of Descriptive Geoenvironmental Mineral Deposit Models. USGS Open-File Report 95-831, http://pubs.usgs.gov/of/1995/ofr-95-0831/. P. 19-27.

Jansons, U., R.B. Hoekzema, J.M. Kurtak, and S.A. Fechner. 1984. Mineral Occurrences in the Chugach National Forest, Southcentral Alaska. USBOM Report MLA 5-84. 219 p.

Kirschner, C.E. 1992. Map Showing Sedimentary Basins in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO, 1994. Plate 7, scale 1:2,500,000.

Kline, J.T. and D.S. Pinney. 1994. Preliminary Map of Selected Occurrences of Industrial Minerals in Alaska: Metallic and Rare-Earth Elements, Nonmetallic, and Construction Materials. DGGS Public-Data File 95-24. 3 map sheets, scale 1:2,500,000.

Kraus, K., mining geologist, Alaska Dept. of Natural Resources. 2004. Verbal communication: status of state mining claims in tidelands areas, and current prospects within Ring of Fire. May 26.

Kurtak, J. 1982. A Manganese Occurrence on Chenega Island, Alaska. USBOM Report MLA 124-82. 9 p.

Liles, P. 2004. Energy Supplies May Be in Hot Water. Alaska Journal of Commerce Online. August 23. www.alaskajournal.com/stories/082304/loc_20040823001.shtml.

Liss, S.A. and M.A. Wiltse. 1993a. USGS Alaska Mineral Resource Appraisal Program (AMRAP) Geochemical Data for Anchorage Quadrangle, Alaska. DGGS Public-Data File 93-39B. 6 p., 1 disk, www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=1574.

Liss, S.A. and M.A. Wiltse. 1993b. USGS AMRAP Geochemical Data for Bradfield Canal Quadrangle, Alaska. DGGS Public-Data File 93-39G. 6 p., 1 disk, www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=1581.

Logan, J.M. 2002. Intrusion-Related Gold Mineral Occurrences of the Bayonne Magmatic Belt. British Columbia Geological Survey, Paper 2002-1. p. 237-246.

Maas, K. 1988. Volume 3 - Industrial Minerals, in USBOM, ed., Mineral Investigations in the Juneau Mining District, Alaska, 1984-1988. BOM Special Publication, Juneau Branch, Alaskan Field Operations Center. 115 p.

Maas, K.M., P.E. Bittenbender, and J.C. Still. 1995. Mineral Investigations in the Ketchikan Mining District, Southeastern Alaska. USBOM Open File Report 11-95. 606 p.

Magoon III, L.B. 1994. Petroleum Resources in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 905-936.

Magoon, L.B. 1996a. Cook Inlet Basin, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Magoon, L.B. 1996b. Cook Inlet Basin, in Gautier, D.L., G.L. Dolton, .I. Takahashi, and K.L. Varnes, eds., 1995 National Assessment of United States Oil and Gas Resources - Results, Methodology, and Supporting Data. USGS Digital Data Series DDS-30, Release 2. 1 disk.

Magoon, L.B. and Z.C. Valin. 1996. Copper River Basin, in Gautier, D.L., G.L. Dolton, .I. Takahashi, and K.L. Varnes, eds., 1995 National Assessment of United States Oil and Gas Resources - Results, Methodology, and Supporting Data. USGS Digital Data Series DDS-30, Release 2. 1 disk.

Magoon, L.B. W.L. Atkinson, and R.M. Egbert. 1976. Map Showing Geology, Wildcat Wells, Tertiary Plant Fossil Localities, K-Ar Age Dates, and Petroleum Operations, Cook Inlet Area, Alaska. USGS Misc. Investigation Series Map I-1019. Scale 1:250,000.

Magoon, L.B., C.M. Molenaar, T.R. Bruns, M.A. Fisher, and Z.C. Valin. 1996. Southern Alaska Province (003), in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Matanuska Electric Association (MEA). 2005. MEA Begins Talks with Usibelli Coal for Future Power Plant in Mat-Su Valley. www.matanuska.com/news/2005/news2005-02-02a.html.

Merritt, R.D. 1984. Alaska Coal Summary - 1983. DGGS Public-Data File 85-21. July. 54 p.

Merritt, R.D. 1986a. Alaska Coal Fields and Seams. DGGS Public-Data File 86-67. August. 30 p.

Merritt, R.D. 1986b. Chronicle of Alaska Coal-mining History. DGGS Public-Data File 86-66. August. 16 p.

Merritt, R.D. 1986c. Evaluation of Alaska's Coal Potential. DGGS Public-Data File 86-92. December.

Merritt, R.D. and C.C. Hawley. 1986. Map of Alaska's Coal Resources. Special Report 37, ADNR, DGGS, in Cooperation with Alaska Coal Association. Scale 1:2,500,000.

Merritt, R.D. and M.A. Relowich. 1984. Coal Geology and Resources of the Matanuska Valley, Alaska. DGGS Report of Investigations 84-24. September

Miller, T.P. 1994. Geothermal Resources of Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 979-987.

Miller, T.P. and D.H. Richter. 1994. Quaternary Volcanism, Alaska Peninsula and Wrangell Mountains, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 759-779.

Minerals Management Service (MMS), Alaska Outer Continental Shelf (OCS) Region. 1995. Gulf of Alaska/Yakutat Planning Area, Oil and Gas Lease Sale 158, Draft Environmental Impact Statement. OCS EIS/EA, MMS 95-0054. December.

MMS, Alaska OCS Region. 1996. Endowments of Undiscovered Conventionally Recoverable Resources and Economically Recoverable Oil and Gas in the Alaska Federal Offshore, as of January 1995. OCS Report MMS 96-0033. www.mms.gov/alaska/re/96_0033/1.htm.

Molenaar, C.M. 1996a. Alaska Peninsula, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National

Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Molenaar, C.M. 1996b. Alaska Peninsula, in Gautier, D.L., G.L. Dolton, .I. Takahashi, and K.L. Varnes, eds., 1995 National Assessment of United States Oil and Gas Resources - Results, Methodology, and Supporting Data. USGS Digital Data Series DDS-30, Release 2. 1 disk.

Moll-Stalcup, E.J., D.A. Brew, and T.L. Vallier. 1994. Latest Cretaceous and Cenozoic Magmatic Rocks of Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plate 5, Scale 1:2,500,000.

Motyka, R.J. and C.J. Nye, eds. 1985. Geological, Geochemical, and Geophysical Surveys of the Geothermal Resources at Hot Springs Bay Valley, Akutan Island, Alaska. DGGS Public Data File 85-48. 136 p., 2 map sheets, scale 1:40,000.

Motyka, R.J. and M.A. Moorman. 1987. Geothermal resources of Southeast Alaska. DGGS Misc. Publication Professional Report 93. 1 sheet, map scale 1:1,000,000.

Motyka, R.J., M.A. Moorman, and S.A. Liss. 1983. Geothermal Resources of Alaska. DGGS Misc. Publication MP 8. 1 sheet, map scale 1:2,500,000.

Motyka, R.J., S.A. Liss, C.J. Nye, and M.A. Moorman. 1993. Geothermal Resources of the Aleutian Arc. DGGS Misc. Publication Professional Report 114. 17 p., 4 sheets, map scale 1:1,000,000.

Nelson, S.W. and M.L. Miller. 2000. Assessment of Mineral Resource Tracts in the Chugach National Forest, Alaska. USGS Open-File Report 00-026. 16 p.

Nichols, J.C. 1999. Minerals Activities Procedures. Ouachita National Forest. www.fs.fed.us/oonf/minerals/welcome.htm. Updated January 27.

Nokleberg, W., T.K. Bundtzen, H.C. Berg, D.A. Brew, D. Grybeck, M.S. Robinson, T.E. Smith, and W. Yeend. 1987. Significant Metalliferous Lode Deposits and Placer Districts of Alaska. USGS Bulletin 1786. 104 p., 2 plates, map scale 1:5,000,000.

Nokleberg, W., T.K. Bundtzen, H.C. Berg, D.A. Brew, D. Grybeck, M.S. Robinson, T.E. Smith, and W. Yeend. 1992. Metallogenic Map of Significant Metalliferous Lode Deposits and Placer Districts in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plate 11, scale 1:2,500,000.

Nokleberg, W.J., G. Plafker, and F.H. Wilson. 1994. Geology of South-Central Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 311-366.

Nowacki, G., P. Spencer, M. Fleming, T. Brock, and T. Jorgenson. 2002. Unified Ecoregions of Alaska: USGS Open-File Report 02-297. Scale 1:4,000,000.

Nye, C.J., R.J. Motyka, D.L. Turner, and S,A, Liss. 1992. Geology and Geochemistry of the Geyser Bight Geothermal Area, Umnak Island, Aleutian Islands, Alaska. DGGS Report of Investigation 92-1. 82 p., 1 map sheet. May.

Orris, G.J. and J.D. Bliss. 1991. Some Industrial Mineral Deposit Models: Descriptive Deposit Models. USGS Open-File Report 91-0011-A. 73 p.

Patton, W.W., S.E. Box, and D.J. Grybeck. 1994. Ophiolites and Other Mafic-Ultramafic Complexes in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 671-686.

Persson, C., Field Office Geologist, BLM Anchorage Field Office. 2004. Verbal Communication, re: criteria for mapping occurrence and development potential of locatable and salable minerals in Ring of Fire. April 26.

Petroleum News. 2001. Marathon Begins Natural Gas Production from Wolf Lake. Vol. 7, No. 149. www.petroleumnews.com/nbarch/07-149-1.html. November 28.

Petroleum News. 2003. Unocal Announces Happy Valley Gas Discovery; KKPL Holds Open Season. Vol. 8, No. 47, Week of November 23. www.petroleumnews.com/pnnew/40869795.html.

Pinney, D.S. and E.S. Duenwald. 2001. Directory of Aggregate, Rock, and Soil Producers in Alaska. DGGS Information Circular 32. October. 19 p.

Plafker, G. and H.C. Berg. 1994. Introduction, in G. Plafker and H.C. Berg, eds., The Geology of NorthAmerica, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 1-16.

Plafker, G., J.C. Moore, and G.R. Winkler. 1994. Geology of the Southern Alaska Margin, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 389-449.

Plafker, G., L.M. Gilpin, and J.C. Lahr. 1993. Neotectonic Map of Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO, 1994. Plate 12, Scale 1:2,5000,000.

Redman, E.C., K.M. Maas, J.M. Kurtak, and L.D. Miller. 1988. Juneau Gold Belt Subarea, in USBOM, ed., Bureau of Mines Mineral Investigations in the Juneau Mining District, Alaska, 1984-1988. Special Publication by BOM Juneau Branch, Alaskan Field Operations Center. Volume 2.-Detailed Mine, Prospect, and Mineral Occurrence Descriptions, Section D. 424 p.

Reger, R.D. 1988. Survey of the Sand-and-Gravel Potential of Legislatively Designated Replacement Pool Lands in Alaska. DGGS Public Data File 88-2. January. 16 p.

Reger, R.D. and D.S. Pinney. 1997. Last Major Glaciation of Kenai Lowland, in S.M. Karl, T.J. Ryherd, and N.R. Vaughn, eds., 1997 Guide to the Geology of the Kenai Peninsula, Alaska. Alaska Geological Society, Anchorage, AK. p. 18-27.

Republic Geothermal, Inc. 1985. The Unalaska Geothermal Exploration Project, Executive Final Report. Report prepared for Alaska Power Authority. 26 p. June.

Resource Data, Inc. (RDI), Alaska Earth Sciences, Inc., and USBOM. 1995. Mineral Terranes and Known Mineral Deposit Areas. Published by BOM. Metadata 5 p. plus ARC/INFO database.

Rice, D.D. 1996. Geologic Framework and Description of Coalbed Gas Plays, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Rice, D.D., B.C. Young, and G.W. Paul. 1996. Methodology for Assessment of Technically Recoverable Resources of Coalbed Gas, in W.R. Beeman, R.C. Obuch, and J.D. Brewton, eds., Digital Map Data, Text, and Graphical Images in Support of the 1995 National Assessment of United States Oil and Gas Resources. USGS Digital Data Series DDS-35. 1 disk.

Rose, A.W. 1966. Geology of Chromite-bearing Ultramafic Rocks Near Eklutna, Anchorage Quadrangle, Alaska. 25 p., 1 map sheet.

Rutledge, F.A., R.L. Thorne, W.H. Kerns, and J.J. Mulligan. 1953. Preliminary Report: Nonmetallic Deposits Accessible to the Alaska Railroad as Possible Sources of Raw Materials for the Construction Industry. USBOM Report of Investigations 4932. 129 p.

Saltus, R., P. Hill, G. Connard, T. Hudson, and A. Barnett. 1999a. Building a Magnetic View of Alaska. USGS Open-File Report 99-0418. http://pubs.usgs.gov/of/1999/ofr-99-0418/aktalk.htm.

Saltus, R.W. and G.C. Simmons. 1997. Composite and Merged Aeromagnetic Data for Alaska: A Website for Distribution of Gridded Data and Plot Files. USGS Open File Report 97-520. http://pubs.usgs.gov/of/1997/ofr-97-0520/. Last modified February 21, 2003.

Saltus, R.W., F.E. Riggle, B.T. Clark, and P.J. Hill. 1999b. Merged Aeroradiometric Data for Alaska: A Web Site for Distribution of Gridded Data and Plot Files. USGS Open-File Report 99-0016. http://pubs.usgs.gov/of/1999/ofr-99-0016/.

Schlumberger-Geoquest. 1996. Cook Inlet Oil & Gas Fields. http:/home.gci.net/~lapres/ciflds.htm. January 1.

Selkregg, L.L. 1974c. Alaska Regional Profiles, Volume IV, Southeast Region. University of AEIDC. Map scale approx. 1:1,000,000. 233 p.

Selkregg, L.L., ed. 1974a. Alaska Regional Profiles, Volume I, Southcentral Region. Prep. by L.L. Selkregg and University of Alaska Arctic Environmental Information and Data Center. Map scale approx. 1:1,000,000. 255 p.

Selkregg, L.L., ed. 1974b. Alaska Regional Profiles, Volume III, Southwest Region. University of AEIDC. Map scale approx. 1:1,000,000. 313 p.

Sherman, G.E., E.M. Williams, and M.P. Meyer. 1997. Mineral Materials Survey of the Seward and Glacier Ranger Districts Road Corridor, Chugach National Forest, Alaska, Volume I: Summary and Site Descriptions. Report prepared by BLM Alaska State Office. 66 p.

Siberling, N.J., D.L. Jones, J.W.H. Monger, and P.J. Coney. 1994. Lithotectonic Terrane Map of Alaska and Adjacent Parts of Canada, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plate 3, Scale 1:2,5000,000.

Smith, S.M. 2001. National Geochemical Database, Reformatted Data from the NURE Hydrogeochemical and Stream Sediment (HSSR) Program. U.S. Geological Survey Open-File Report 97-492, version 1.30. http://pubs.usgs.gov/of/1997/ofr-97-0492/.

Smith, T.N. 1995. Coalbed Methane Potential for Alaska and Drilling Results for the Upper Cook Inlet Basin. Intergas '95 Conference, Tuscaloosa, AL, Paper 9501, 21 p. In Barker, C.E., J.G. Clough, and T.A. Dallegge, eds., Coalbed Methane Prospects of the Upper Cook Inlet - Field Trip Guidebook. February 2001. DGGS Misc. Publication MP 41, Submitted Paper D. www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=2731.

Sorden, S. 2002. Quartz. www.geocities.com/quartz_project. Accessed August 30, 2004.

Stiles, R.B. 2002. The Future of Alaskan Coal Production & Utilization. Presentation at The Future of Fossil Energy in Alaska, April 11. www.uaf.edu/aetdl/stiles.pdf.

Still, J.C. 1988. Glacier Bay Subarea, in U.S. Bureau of Mines (BOM), ed., Bureau of Mines Mineral Investigations in the Juneau Mining District, Alaska, 1984-1988. Special Publication by USBOM Juneau Branch, Alaskan Field Operations Center. Volume 2.- Detailed Mine, Prospect, and Mineral Occurrence Descriptions, Section B. 69 p.

Still, J.C., P.E. Bittenbender, W. Bean, and E.G. Gensler. 2002. Mineral Assessment of the Stikine Area, Central Southeast Alaska. BLM-Alaska Technical Report 51. 560 p. May.

Swenson, R.F. 1997. Introduction to Tertiary Tectonics and Sedimentation in the Cook Inlet Basin, in S.M. Karl, T.J. Ryherd, and N.R. Vaughn, eds., 1997 Guide to the Geology of the Kenai Peninsula, Alaska. Alaska Geological Society, Anchorage, AK. p. 18-27.

Szumigala, D.J. 1999. Map of Prospective Mineral Areas and Significant Mineral Resources in Alaska. DGGS Misc. Publication MP 38. 1 map sheet, scale 1:2,500,000. 63 p.

Szumigala, D.J., R.C. Swainbank, M.W. Henning, and F.M. Pillifant. 2002. Alaska's Mineral Industry 2002. DGGS Special Report 57. 63 p.

Thiel, R. and M.A. Smith. 2003. State of the Practice Review of Heap Leach Pad Design Issues. Conference Proceedings, Bi-annual Meeting of the Geosynthetics Research Institute, Las Vegas, Nevada. December.

Thrush, P.W., ed. 1968. A Dictionary of Mining, Mineral, and Related Terms. USBOM. 1269 p.

Turner, D.L. and E.M. Wescott, eds. 2004. Geothermal Energy Resource Investigations at Mt. Spurr, Alaska. Geophysical Institute, University of Alaska, UAG R-308a. U.S. Department of Energy Grant No. DE-FG07-841D2471. 105 p., 5 plates. Revised October 2004.

Tyler, R., A.R. Scott, and J.G. Clough. 2000. Coalbed Methane Potential and Exploration Targets for Rural Alaska Communities. DGGS Preliminary Investigative Report 2000-2. February. 177 p.

Tysdal, R.G. and J.E. Case. 1979. Geologic Map of the Seward and Blying Sound Quadrangles, Alaska. USGS Misc. Investigation Series Map I-1150. 12 p., map scale 1:250,000.

U.S. Environmental Protection Agency (USEPA). 1990. Diamond Chuitna Coal Project, Final Environmental Impact Statement. EPA 910/9-89-011. 2 vol. February.

U.S. Bureau of Mines (USBOM). 1988. Mineral Investigations in the Juneau Mining District, Alaska, 1984-1988. USBOM Special Publication, Juneau Branch, Alaskan Field Operations Center. 3 volumes.

USBOM. 1995. Mineral Availability System/ Minerals Industry Location System (MAS/MILS) CD-ROM, Data Dictionary. BOM Special Publication 12-95. Metadata 45 p. plus database.

U.S. Department of Energy (USDOE) Energy Efficiency and Renewable Energy. 2004a. Geothermal Technologies Program. www.eere.energy.gov/geothermal/solicitations_awards.html. Updated August 24.

USDOE Energy Information Administration. 2004b. Glossary of Coal Industry Terms. www.eia.doe.gov/cneaf/coal/page/gloss.html. Last modified March 17.

U.S. Forest Service (USFS). 2000. Draft Environmental Impact Statement, Chugach National Forest Land Management Plan Revision, Alaska. p.3-392 to 3-412. May.

USFS. 1997. Final Environmental Impact Statement, Tongass National Forest Land Management Plan Revision, Alaska. p.3-89 to 3-95. May.

U.S. Fish and Wildlife Service (USFWS). 1985. Alaska Peninsula National Wildlife Refuge, Final Comprehensive Plan, Environmental Impact Statement and Wilderness Review. USFWS, Anchorage, Alaska. 426 pp. August.

USFWS. 1987. Kodiak National Wildlife Refuge, Final Comprehensive Plan, Wilderness Review, and Environmental Impact Statement. USFWS, Anchorage, Alaska. 533 p. April.

USFWS. 1988. Alaska Maritime National Wildlife Refuge, Final Comprehensive Plan, Wilderness Review, and Environmental Impact Statement. USFWS, Anchorage, Alaska. August.

U.S. Geological Survey (USGS) National Oil and Gas Resource Assessment Team. 1995. 1995 National Assessment of United States Oil and Gas Resources. USGS Circular 1118. 20 p.

USGS. 2002. Aeromagnetic Surveys in the Anchorage, Illiamna, and Tyonek Quadrangles Alaska, A Website for the Distribution of Data. USGS Open-File Report 02-0267. http://pubs.usgs.gov/of/2002/ofr-02-0267/ofr-02-0267.html. Last modified January 26, 2004.

USGS. 2004a. The Alaska Resource Data Files (ARDF). http://ardf.wr.usgs.gov/. Last updated April 16.

USGS. 2004b. Geochemistry of Igneous Rocks from the PLUTO Database.http://tin.er.usgs.gov/pluto/igneous/select.php?place=fUS02&div=fips&map=on. Last updated May 6.

USGS. 2004c. National Geochemical Survey – Database and Documentation. U.S. Geological Survey Open-File Report 2004-1001, version 1.0. http://tin.er.usgs.gov/geochem/doc/home.htm Last modified January 6.

Usibelli Coal, Inc. (Usibelli). 2004. Chronology. www.usibelli.com/chron.html. Accessed June 29, 2005.

Vallier, T.L., D.W. Scholl, M.A. Fisher, T.R. Bruns, F.H. Wilson, R. von Huene, and A.J. Stevenson. 1994. Geologic Framework of the Aleutian Arc, Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 367-388.

VECO Corporation. 2002. What's New: Marathon Oil Corporation Chooses VECO. www.veco.com/WhatsNew/0211-01.asp. November.

Wahraftig, C., S. Bartsch-Winkler, and G.D. Stricker. 1994. Coal in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. p. 937-978.

Wahrhaftig, C. 1965. Physiographic Divisions of Alaska. USGS Professional Paper 482. Scale 1:2,500,000, 52 p.

Warfield, R.S. 1962. Some Nonmetallic Mineral Resources for Alaska's Construction Industry. USBOM Report of Investigations 6002.

Wescott, E.M., D.L. Turner, C.J. Nye, J.E. Beget, and R.J. Motyka. 1985. Preliminary Report on Geothermal Resource Investigations at Mt. Spurr, Alaska. DGGS Public-Data File 85-65. 17 p. December.

Williams, E. and R. Ellefson, geologists, BLM, Anchorage, Alaska. 2004. Verbal communication, re: electronically available data, maps, and reports for locatable minerals in the Ring of Fire. April 30.

Wilson, F.H., N. Shew, and G.D. DuBois. 1994. Map and Table Showing Isotopic Age Data in Alaska, in G. Plafker and H.C. Berg, eds., The Geology of North America, Volume G-1, The Geology of Alaska. Geological Society of America, Boulder, CO. Plate 8.

Wiltse, M.A. 1991a. NURE Geochemical Data for Stream and Lake Sediment Samples, Alaska, Anchorage Quadrangle. DGGS Public Data File 91-22A. 33 p., 1 disk, www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=1492.

Wiltse, M.A. 1991b. NURE Geochemical Data for Stream and Lake Sediment Samples, Alaska, Talkeetna Mountains Quadrangle. DGGS Public Data File 91-KK. 33 p., 1 disk, www.dggs.dnr.state.ak.us/pubs/pubs?reqtype=citation&ID=1502.

Wohletz K. and G. Heiken. 1992. Volcanology and Geothermal Energy. University of California Press, Berkeley, CA. p. 261-294.

Wood, G.H., T.M. Kehn, M.D. Carter, and W.C. Culbertson. 2003. Coal Resource Classification System of the USGS. USGS Circular 891. http://pubs.usgs.gov/circ/c891/index.htm.

Wynn, J., J. Douchette, S. Karl, A. McCafferty, B. Smith, and P. Bittenbender. 2001. Geophysical Signatures Used to Constrain Geologic Mapping: Narrowing the Search for VMS Deposits in Southeast Alaska. USGS Open File Report 01-44, online version 1.0. http://pubs.usgs.gov/of/of01-044/.

Tables

TABLE 1
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL	NAME AND DESCRIPTION
	STRATIFIED SEDIMENTARY SEQUENCE
Qh	HOLOCENE DEPOSITS - Alluvial, glacial, lake, estuarine, swamp, landslide, flood plain, and beach deposits.
Q	QUATERNARY DEPOSITS – Alluvial, glacial, lake, eolian, beach, and volcanic deposits. Includes the marine Bootlegger Cove Clay.
Qp	PLEISTOCENE DEPOSITS – Alluvial, glacial, dune sand, loess, and reworked sand and silt deposits.
Tp	PLIOCENE ROCKS – Sandstone, siltstone, and conglomerate. Includes Tachilni Formation on the Alaska Peninsula, and Tugidak Formation on Tugidak and Chirkof Islands.
UT	UPPER TERTIARY ROCKS – Mostly marine sandstone, siltstone, shale, mudstone, and conglomerate of Miocene and Pliocene age. Includes Yakataga Formation in the Gulf of Alaska area.
uTc	UPPER TERTIARY CONTINENTAL DEPOSITS – Sandstone, siltstone, claystone, minor conglomerate, and coal beds. Includes upper part of Kenai Group in Cook Inlet area. Rocks range in age from Oligocene(?) through Pliocene.
Tm	MIOCENE ROCKS – Sandstone, siltstone, conglomerate, argillite, graywacke, and basaltic rocks. Includes Bear Lake Formation on the Alaska Peninsula, Narrow Cape Formation (Oligocene or Miocene) on Kodiak and Sitkinak Islands, and Chuniksak Formation (Miocene?) on Attu Island.
To	OLIGOCENE ROCKS – Volcanic conglomerate, sandstone, volcanic breccia, shale, and siltstone. Includes the Meshik Formation and Stepovak Formation on the Alaska Peninsula and the Sitkinak Formation on Sitkalidak, Sitkinak, and Chirikof Islands.
Te	EOCENE ROCKS – Sandstone, siltstone, and shale interbedded with mafic flows and sills of the Andrew Lake Formation on Adak Island.
T	TERTIARY ROCKS – Volcanogenic sedimentary rocks and flows, dikes, and sills on the Alaska Peninsula and Umnak Island.
Tc	TERTIARY CONTINENTAL DEPOSITS – Sandstone, coal, conglomerate, and shale of the Kootznahoo Formation on Admiralty, Kuiu, Kupreanof, and Zarembo Islands.
MT	MIDDLE TERTIARY ROCKS – Mostly marine siltstone, sandstone, organic shale, and locally, volcanic rocks. Includes Poul Creek, Katalla, and Topsy Formations ranging from Oligocene to Miocene age in Gulf of Alaska area.
mTc	MIDDLE TERTIARY CONTINENTAL DEPOSITS – Sandstone, siltstone, claystone, and coal beds. Includes the Tsadaka Formation in Matanuska Valley. Rocks range in age from Oligocene through Miocene.
lT	LOWER TERTIARY ROCKS – Mostly marine interbedded sedimentary, volcanogenic, and volcanic rocks of Paleocene, Eocene, and Oligocene age on Alaska Peninsula and Aleutian Islands; and intensely deformed marine and continental clastic rocks of Paleocene and Eocene age in the Gulf of Alaska area. Includes Tolstoi and Belkofski Formations in the Alaska Peninsula; Ghost Rocks Formation on Kodiak Island; Amchitka and Banjo Point Formations on Amchitka Island; Gunners Cove Formation on Rat Island; Krugloi Formation on Agattu Islands; and Kulthieth, Kushtaka, and Tokun Formations and clastic rocks of the Orca Group in the Gulf of Alaska area.
lTc	LOWER TERTIARY CONTINENTAL DEPOSITS – Claystone, siltstone, sandstone, conglomerate, and coal beds. Includes the Chickaloon and Wishbone Formations in Matanuska Valley. Rocks range in age from Paleocene through Oligocene.
Txc	PALEOCENE CONTINENTAL DEPOSITS – Conglomerate, sandstone, coaly shale, and shale.

TABLE 1 (Cont.)
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL		NAME AND DESCRIPTION
		STRATIFIED SEDIMENTARY SEQUENCE (CONT.)
	TKc	TERTIARY AND CRETACEOUS CONTINENTAL DEPOSITS – Conglomerate, breccia, sandstone, arkose, mudstone, shale, tuffaceous rocks, and lignite. Includes Arkose Ridge Formation (Cretaceous?) in Matanuska Valley.
	uK	UPPER CRETACEOUS ROCKS – Nonmarine and marine classic rocks, siltstone, and shale of the Chignik and Hoodoo Formations on the Alaska Peninsula; graded beds of sandstone and slate of the Kodiak Formation on Kodiak and Afgonak Islands; sandstone and mudstone of Shumagin Formation on Shumagin and Sanak Islands.
	K	CRETACEOUS ROCKS – Includes the Matanuska Formation in Matanuska Valley; and the Kaguyak Formation on Alaska Peninsula.
	lK	LOWER CRETACEOUS ROCKS – Unnamed graywacke, argillite, and minor andesite on Etolin Island.
	KJ	CRETACEOUS AND JURASSIC ROCKS – Argillite, shale, graywacke, quartzite, conglomerate, lava, tuff, and agglomerate. Almost barren of fossils and probably includes rocks ranging in age from Early Jurassic to Late Cretaceous. In places moderately to highly metamorphosed (amphibolite facies).
	KJ_1	CRETACEOUS AND UPPER JURASSIC ROCKS – Graywacke, slate, argillite, minor conglomerate, volcanic detritus, and interbedded mafic volcanic rocks. Includes Valdez and part of Yakutat Groups and Sitka Graywacke. Mildly metamorphosed, locally to greenschist.
	KJ_2	LOWER CRETACOUS AND UPPER JURASSIC ROCKS – Includes sandstone, arkose, siltstone, and limestone of the Staniukovich Formation and Herendeen Limestone on the Alaska Peninsula; and slate, graywacke and conglomerate of the Seymour Canal Formation on Admiralty and Kupreanof Islands.
	KJ_3	LOWER CRETACEOUS AND UPPER JURASSIC(?) ROCKS – Melange of flysch, greenstone, limestone, chert, granodiorite, glaucophane-bearing greenschist, and layered gabbbro and serpentenite. Melange consists of Upper Jurassic(?) and Lower Cretaceous pelitic matrix enclosing blocks several kilometers in dimension of Permian to Lower Jurassic rocks. Includes the Uyak Formation, McHugh Complex, mélange within the Yakutat Group, and Waterfall Greenstone and Khaz Formation of the Kelp Bay Group.
	uJ	UPPER JURASSIC ROCKS – Sandstone, siltstone, shale, and conglomerate on the Alaska Peninsula, Cook Inlet area, and southern flank of Talkeetna Mountains. Includes the Chinitna and Naknek Formations.
	mJ	MIDDLE JURASSIC ROCKS – Sandstone, shale, siltstone, and conglomerate on the Alaska Peninsula and Cook Inlet area where it includes the Kialagvik and Shelikof Formations and Tuxedni Group.
	lJ	LOWER JURASSIC ROCKS – Sandstone and argillite interbedded with volcanic flows and pyroclastic rocks of the Talkeetna Formation in the Cook Inlet area and southern Talkeetna Mountains.
	JTR	JURASSIC AND/OR TRIASSIC ROCKS – Hornfels and phyllite of the Hazelton(?) Group in southeast Alaska.

TABLE 1 (Cont.)
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL	NAME AND DESCRIPTION
	STRATIFIED SEDIMENTARY SEQUENCE (CONT.)
uTR	UPPER TRIASSIC ROCKS – Limestone, shale, and chert of the Kamishak Formation in the Cook Inlet area; a shelf facies of limestone, tuff, tuffaceous conglomerate and breccias at the southern tip of the Kenai Peninsula (west of the Border Ranges fault) and equivalent rocks on Shuyak, Afognak, and Kodiak Islands; a deep water flysch and mélange facies of chert, pillow basalt and associated graywacke, argillite, and minor ultramafic rocks (east of the Border Ranges fault) on the southern Kenai Peninsula; chert, limestone, sandstone, and greenstone of the Whitestripe Marble and Pinnacle Peak Phyllite (both Triassic?) on Chichagof and Baranof Islands, of the Hyd Group on Admiralty Island and Keku Straits area, and of the Nehenta and Chapin Peak Formations on Gravina Island.
TRP	TRIASSIC AND PERMIAN ROCKS – Schist, graywacke, slate, conglomerate, phyllite, andesite flows and tuffs on Admiralty Island where it includes the Barlow Cove Formation.
MzPz	MESOZOIC AND PALEOZOIC ROCKS – Lower Jurassic, Pennsylvanian, and Permian rocks, in part covered by Tertiary sedimentary rocks and intruded by granitic rocks of Tertiary age in north-central Chugach Mountains; and slate, quartzite, schist, and phyllite with interlayered beds of marble, layered gneiss and amphibolite of Ordovician to Jurassic or Cretaceous age along the wet flank of the Coast Mountains.
P	PERMIAN ROCKS – Volcanic argillite and graywacke with local chert, pillow flows, limestone, and dolomite of the Cannery, Pybus, and Halleck Formations on Admiralty, Kuiu, and Kupreanof Islands.
PIP	PERMIAN AND PENNSYLVANIAN ROCKS – Basaltic to andestic lavas and derivative volcaniclastic rocks, tuffs, minor gabbro, and local shallow-water sedimentary rocks metamorphosed to greenschist facies, and locally, amphibolite facies. Includes Skolai Group, Strelna Formation (Permian), and Tetelna Volcanics in the Talkeetna Mountains. Consists of unnamed phyllite, slate, schist, greenschist, amphibolite, gneiss, and migmatite in St. Elias Mountains.
IP	PENNSYLVANIAN ROCKS – Siltstone, sandstone, and limestone of the Klawak Formation and Ladrones Limestone on Prince of Wales Island.
M	MISSISSIPPIAN ROCKS – Limestone, dolomite, and interbedded chert of the Iyoukeen Formation on Chichagof Island and Peratovich Formation on Prince of Wales Island.
uPz	UPPER PALEOZOIC ROCKS – Argillite, chert, shale, limestone, and siltstone. Greenstone, limestone, shale, clastic sedimentary rocks, schist, gneiss, and undifferentiated metamorphic rocks east of Juneau.
Pz	PALEOZOIC ROCKS – Sedimentary, metasedimentary, and metavolcanic rocks in southeastern Alaska.
D	DEVONIAN ROCKS – Clastic rocks and limestone of the Kennel Creek Limestone (which may also include Silurian rocks) and Cedar Cove Formation on Chichagof Island; schist, phyllite, marble, and amphibolite of the Retreat Group and Gambler Bay Formation on Admiralty and Kupreanof Islands and equivalent rocks to the north and south; and limestone, shale, graywacke, conglomerate and basaltic rocks of the St. Joseph Island Volcanics (Devonian?), Wadleigh Limestone, and Port Refugio Formation on Prince of Wales Island.
DS	DEVONIAN AND SILURIAN ROCKS – Limestone, dolomite, marble, and shale of the Karheen Formation in Prince of Wales Island.

TABLE 1 (Cont.)
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL		NAME AND DESCRIPTION
		STRATIFIED SEDIMENTARY SEQUENCE (CONT.)
	S	SILURIAN ROCKS – Graywacke, shale, siltstone, limestone, sandstone, and argillite. Includes siltstone, mudstone, limestone, conglomerate, sandstone, graywacke, minor red beds and volcanic rocks of the Rendu Formation, and Willoughby Limestone in Glacier Bay areas, the Point Augusta Formation on Chichagof Island; Bay of Pillars Formation on Admiralty, Kuiu, and Prince of Wales Islands; and Kuiu Limestone and Heceta Limestone on Prince of Wales Island.
	O	ORDOVICIAN ROCKS – Argillite, chert, and limestone of the Hood Bay Formation on Admiralty Island.
	SO	SILURIAN AND ORDOVICIAN ROCKS – Graywacke, conglomerate, shale, siltstone, tuff, lava, and local limestone of the Descon Formation on Prince of Wales Island.
	IPzp€	LOWER PALEOZOIC AND/OR PRECAMBRIAN ROCKS – Volcanogenic greenschist with interstratified marble in Prince of Wales, Long and Dall Islands, where it includes the Wales Group and possibly Descon Formation.
		METAMORPHIC ROCKS
	IJm	LOWER JURASSIC METAMORPHIC ROCKS – Intercalated blue schist, quartz mica schist, greenschist with subordinate amphibolite, marble, and metachert at southern tip of Kenai Peninsula and on Afognak Island.
	Mzm	MESOZOIC METAMORPHIC ROCKS – Small masses of metamorphosed sedimentary, volcanic, and igneous rocks, largely of pre-Cretaceous age, scattered throughout the Aleutian Range batholith. Amphibolite facies schist along north side of Matanuska Valley.
	JPm	JURASSIC, TRIASSIC, AND PERMIAN METAMORPHIC ROCKS – Metasedimentary, metaplutonic, and metavolcanic rocks near Anchorage and along south side of Matanuska Valley.
	Pzm	PALEOZOIC METAMORPHIC ROCKS – Hornfels, schist, amphibolite, minor marble, and undivided metamorphic rocks north of Icy Strait in southeastern Alaska.
		VOLCANIC ROCKS
	Qhvf	QUATERNARY – HOLOCENE volcanic rocks of felsic composition
	Qhvi	QUATERNARY – HOLOCENE volcanic rocks of intermediate composition
	Qhvm	QUATERNARY – HOLOCENE volcanic rocks of mafic composition
	Qhv	QUATERNARY – HOLOCENE volcanic rocks, undifferentiated
	Qpvi	QUATERNARY – PLEISTOCENE volcanic rocks of intermediate composition
	Qpv	QUATERNARY – PLEISTOCENE volcanic rocks, undifferentiated
	Qvi	QUATERNARY volcanic rocks of intermediate composition
	Qvm	QUATERNARY volcanic rocks of mafic composition
	Qv	QUATERNARY volcanic rocks, undifferentiated
	QTv	QUATERNARY or TERTIARY volcanic rocks, undifferentiated
	Tpv	TERTIARY – PLIOCENE volcanic rocks, undifferentiated
	Tmvi	TERTIARY – MIOCENE volcanic rocks of intermediate composition
	Tmv	TERTIARY – MIOCENE volcanic rocks, undifferentiated
	uTv	UPPER TERTIARY volcanic rocks, undifferentiated
	lTvi	LOWER TERTIARY volcanic rocks of intermediate composition
	lTvm	LOWER TERTIARY volcanic rocks of mafic composition

TABLE 1 (Cont.)
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL	NAME AND DESCRIPTION
VOLCANIC ROCKS (CONT.)	
lTv	LOWER TERTIARY volcanic rocks, undifferentiated
Tvf	TERTIARY volcanic rocks of felsic composition
Tvi	TERTIARY volcanic rocks of intermediate composition
Tvm	TERTIARY volcanic rocks of mafic composition
Tv	TERTIARY volcanic rocks, undifferentiated
Kvi	CRETACEOUS volcanic rocks of intermediate composition
KJvm	CRETACEOUS and/or JURASSIC volcanic rocks of mafic composition
Ꞧvm	TRIASSIC volcanic rocks of mafic composition
Mzvm	MESOZOIC volcanic rocks of mafic composition
MzPzvm	MESOZOIC and PALEOZOIC volcanic rocks of mafic composition
Dv	DEVONIAN volcanic rocks, undifferentiated
INTRUSIVE ROCKS	
Tmif	TERTIARY – MIOCENE intrusive rocks of felsic composition
Tmim	TERTIARY – MIOCENE intrusive rocks of mafic composition
Toif	TERTIARY – OLIGOCENE intrusive rocks of felsic composition
mTii	MIDDLE TERTIARY intrusive rocks of intermediate composition
mTim	MIDDLE TERTIARY intrusive rocks of mafic composition
Teif	TERTIARY – EOCENE intrusive rocks of felsic composition
Txif	TERTIARY – PALEOCENE intrusive rocks of felsic composition
Tif	TERTIARY intrusive rocks of felsic composition
Tii	TERTIARY intrusive rocks of intermediate composition
Tim	TERTIARY intrusive rocks of mafic composition
Ti	TERTIARY intrusive rocks, undifferentiated
TKif	TERTIARY and/or CRETACEOUS intrusive rocks of felsic composition
TKii	TERTIARY and/or CRETACEOUS intrusive rocks of intermediate composition
TKim	TERTIARY and/or CRETACEOUS intrusive rocks of mafic composition
TKi	TERTIARY and/or CRETACEOUS intrusive rocks, undifferentiated
Kif	CRETACEOUS intrusive rocks of felsic composition
Kii	CRETACEOUS intrusive rocks of intermediate composition
Kim	CRETACEOUS intrusive rocks of mafic composition
Ki	CRETACEOUS intrusive rocks, undifferentiated
KJii	CRETACEOUS and/or JURASSIC intrusive rocks of intermediate composition
Jif	JURASSIC intrusive rocks of felsic composition
Jii	JURASSIC intrusive rocks of intermediate composition
Jim	JURASSIC intrusive rocks of mafic composition
INTRUSIVE ROCKS (CONT.)	

TABLE 1 (Cont.)
LEGEND FOR GEOLOGIC MAPS
Ring of Fire Planning Area, Alaska

SYMBOL		NAME AND DESCRIPTION
	Mzii	MESOZOIC intrusive rocks of intermediate composition
	Mzi	MESOZOIC intrusive rocks, undifferentiated
	MzPzii	MESOZOIC and PALEOZOIC intrusive rocks of intermediate composition
	MzPzi	MESOZOIC and PALEOZOIC intrusive rocks, undifferentiated
	Pi	PERMIAN intrusive rocks, undifferentiated
	Sii	SILURIAN intrusive rocks of intermediate composition
	Oi	ORDOVICIAN intrusive rocks, undifferentiated
	Pzii	PALEOZOIC intrusive rocks of intermediate composition
	i	intrusive rocks, age unknown, undifferentiated
ULTRAMAFIC ROCKS		
	Ku	CRETACEOUS ultramafic rocks
	Mzu	MESOZOIC ultramafic rocks
	MzPzu	MESOZOIC and PALEOZOIC ultramafic rocks
	Ou	ORDOVICIAN ultramafic rocks
	u	ultramafic rocks, age unknown
MAP SYMBOLS		
✳	VOLCANO, volcanic vent, or intrusive crater	
	FAULT, dashed where concealed or inferred	
	STRIKE-SLIP FAULT, dashed where concealed or inferred	
	THRUST FAULT, dashed where concealed or inferred	

Source: Beikman (1980)

TABLE 2
GEOCHEMISTRY, RESERVOIR CHARACTERISTICS, AND PRODUCTION DATA FOR ONSHORE OIL AND GAS FIELDS OF COOK INLET BASIN
Ring of Fire Planning Area, Alaska

FIELD/UNIT NAME	YEAR DISCOVERED	LAND STATUS	PRODUCING UNIT	MEMBER OR POOL[2]	RESEVOIR LITHOLOGY	PRODUCTION STATUS	TRAP TYPE	CUMULATIVE PRODUCTION[3]		ESTIMATED RESERVES		PRODUCTION DEPTH (FEET)	NET PAY (FEET)	POROSITY (%)	PERMEABILITY (MD)	ORIGINAL GAS/OIL RATIO (SCF/STB)	WATER SATURATION (%)	UNIT AREA (ACRES)	OIL CHEMISTRY		GAS CHEMISTRY		
								OIL ($X10^3$ BBL)	GAS (BCF)	OIL ($X10^6$ BBL)	GAS (BCF)								OIL GRAVITY (API)	SULFUR (%)	GAS SPECIFIC GRAVITY	BTU (BTU/FT^3)	METHANE FRACTION (%)
OIL FIELDS – KENAI PENINSULA																							
Swanson River	—	Federal/Native	Hemlock	Soldotna	conglomerate	producing	faulted anticline	—	—	—	—	10,300	220	20-24	40-360	350	40	—	36.5	—	—	—	—
Swanson River	—	Federal/Native	Hemlock	34-10	conglomerate	producing	faulted anticline	—	—	—	—	10,560-10,770	145	20-21	55-75	175	40	—	30	0.1	—	—	—
Swanson River	1957	Federal/Native	Field Total					230,000	3,200	4	50							7,880					
Beaver Creek	1972	Federal	Tyonek	Beaver Creek	sandstone/ conglomerate	producing	—	5,800	2	0.26	—	14,790	100	—	—	380	—	825	35	<0.1	—	—	—
GAS FIELDS – KENAI PENINSULA																							
Kenai	1959	Federal/Native/State	Sterling	A, 3-6	sandstone	producing	dome	—	1,850	—	—	3,710-4,565	420	35.5	—	—	35	—	—	—	0.577	—	99.9
Kenai	1959	Federal/Native/State	Beluga – Upper Tyonek	—	sandstone	producing	dome	—	260	—	—	4,000-4,990	215	15-20	—	—	40	—	—	—	0.555	—	—
Kenai	1959	Federal/Native/State	Deep Tyonek	Tyonek	sandstone	producing	dome	11	190	—	—	9,000	100	18-22	—	—	40	—	—	—	0.560	—	99.8
Kenai	1959	Federal/Native/State	Field Total					11	2,300	0	60							8,264				1,005	98.9
Swanson River	1960	Federal	Sterling	B,D,E Sands	sandstone	producing	anticline	—	43	—	—	2,870-7,500	—	30	650	—	35	640	—	—	0.600	1,002	99.9
West Fork	1960	Native	Sterling	—	sandstone	shut-in	faulted anticline	0	4.2	—	3	4,990	25	30	4,400	—	—	457	—	—	0.560	—	—
Falls Creek	1961	State	Tyonek	MGS	sandstone	shut-in	—	0	0.019	—	10	4,690-7,040	189	15-25	6	—	—	564	—	—	0.600	1,015	99.1
Sterling	1961	Federal/Native/State	Sterling - Tyonek	—	sandstone	producing	dome	0	4.3	—	20	5,030-9,450	180	10-26	0.1-125	—	40	3,600	—	—	0.560 - 0.569	991	99.8
Birch Hill	1965	Federal/Native	Tyonek	MGS	sandstone	shut-in	faulted dome	0	0.065	—	10	7,690	30	25	5-6	—	—	1,240	—	—	0.561	1,014	98.6
North Fork	1965	Federal/State	Tyonek	MGS	sandstone	shut-in	—	0	0.105	—	10	7,200	40	18	3.5	—	50	50	—	—	0.562	1,002	98.1
Beaver Creek	1967	Federal	Sterling	Sterling	sandstone	producing	dome	—	120	—	—	5,000	110	30	2,000	—	40	—	—	—	0.570	—	98.9
Beaver Creek	1967	Federal	Beluga	Beluga	sandstone	producing	dome	—	40	—	—	8,100	50	10	—	—	—	—	—	—	—	—	—
Beaver Creek	1967	Federal	Field Total					—	160		80							4,960				998	98.3
Cannery Loop	1979	State	Beluga - Sterling	Beluga - Tyonek	sandstone	producing	—	<1	111	—	4	4,965-10,000	150	—	25-250	—	—	1,900	—	—	0.556 – 0.562	—	—
Wolf Lake	1998	Native	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ninilchik/ South Ninilchik	2001	State/Native	Tyonek	Oskolkoff, Dionne	sandstone	producing	anticline	—	2.1	—	90	3,338-3,496	97-233	15-21	8-14	—	—	34,858	—	—	—	—	—
Deep Creek	2003	State/Native	—	—	—	exploration	—	0	0	—	75-100	—	110	—	—	—	—	22,617	—	—	—	—	—
GAS FIELDS – WEST SIDE OF COOK INLET																							
West Foreland	1962	Native	Tyonek	MGS	sandstone	shut-in	—	—	—	—	20	—	25	—	—	—	—	640	—	—	0.600	929	92.1
Beluga River	1962	Native/State	Sterling	—	sandstone	producing	anticline	—	—	—	—	3,300	110	31	—	—	37	—	—	—	0.556	—	—
Beluga River	1962	Native/State	Beluga	—	sandstone	producing	anticline	—	—	—	—	4,000-4,490	105	24	—	—	42	—	—	—	0.556	—	—
Beluga River	1962	Native/State	Field Total					0	850	0	320							12,743				1,014	99.7
Moquawkie	1965	Federal/Native	Tyonek	—	sandstone	shut-in	—	0	0.984	—	—	2250	106	20-24	20-50	—	35-40	1,280	—	—	0.560	1,006	99.0
Nicolai Creek	1966	State	Beluga-Tyonek	A, B	sandstone	producing	—	0	1.67	—	1	2,160	35	—	—	—	—	9,123	—	—	0.575	976	99.5
Ivan River	1966	State	Tyonek	Chuitna	sandstone	producing	dome	0	72	—	35	7,790	35	20	1,600	—	45	9,301	—	—	0.560	1,004	98.9
Albert Kaloa	1968	Native	Tyonek	—	sandstone	shut-in	—	0	0.119	—	—	3,210	—	—	—	—	—	—	—	—	—	—	—
Lewis River	1975	State	Beluga	—	sandstone	producing	faulted anticline	0	10.3	—	10	4,710	85	22	45	—	—	3,200	—	—	0.566	—	—
Stump Lake	1978	State	Beluga	—	sandstone	shut-in	anticline	0	5.6	—	<1	6,690-6,740	91	24	5	—	—	13,691	—	—	0.558	—	—
Pretty Creek/ Theodore River	1979	State	Beluga	—	sandstone	producing	anticline	0	7	—	<1	3,710-6,000	60	22	—	—	—	6,718	—	—	0.559	—	—
Pioneer	1999	State/Native	Tyonek	—	coal	exploration	—	—	0.002	—	—	—	>100	—	—	—	—	49,263	—	—	—	—	98

Sources: ADNR/DOG (2002, 2003c, 2004f), AOGCC (2004), Evergreen Resources (2003b), Magoon (1994), Petroleum News (2001, 2003), Schlumberger-Geoquest (1996), Smith (1995), Veco (2002).
— = information not available
% = percent
API = American Petroleum Institute
bbl = barrel
bcf = billion cubic feet
BTU/ft^3 = British Thermal Unit/cubic foot
Md = millidarcy
MGS = Middle Ground Shoal Member
SCU = Soldotna Creek Unit
SCF/STB = standard cubic feet of gas per stock tank barrel of oil

1. Federal includes federal, federal-leased, native-selected, and state-selected lands. State includes state, state-leased, and mental health trust lands.
2. Industry pool designation.
3. Approximate cumulative production through 2002-2003 (ADNR/DOG, 2003c; AOGCC, 2004).

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TABLE 3
LOCATABLE MINERAL TERRANE UNITS[1]
Ring of Fire Planning Area, Alaska

Map Unit	Rock Type	Locatable Mineral Commodities
SYNGENETIC DEPOSITS		
Intrusive Terranes		
IGA	ALKALIC GRANITIC ROCKS – syenite, and locally peralkaline granite and monzonite	Favorable for deposits of U, REE, Mo
IGF	FELSIC GRANITIC ROCKS – granite and quartz monzonite	Favorable for deposits of Sn, W, Mo, U, Th
IGI	INTERMEDIATE GRANITIC ROCKS – granodiorite and quartz diorite	Favorable for Deposits of Cu, Au, Mo
IGU	UNDIVIDED GRANITIC ROCKS – may include mineral deposits of the three above groups	
IMA	MAFIC INTRUSIVE ROCKS – gabbro, and locally mafic-rich intermediate rocks such as mafic monzonite and diorite	Favorable for deposits of Cu, Ni, with byproduct Pt, Co
IUM	ULTRAMAFIC ROCKS – peridotite and dunite	Favorable for deposits of Cr, Ni, PGE with byproduct Co
Volcanic – Sedimentary Terranes		
VFU	FELSIC VOLCANIC ROCKS, undivided – rhyolite and quartz latite	Favorable for deposits of Cu, Pb, Zn with byproduct Ag, Au
VFI	INTERMEDIATE VOLCANIC ROCKS – trachyandesite, andesite	Favorable for deposits of U, Th
VMU	MAFIC VOLCANIC ROCKS, undivided – primarily basalt	Favorable for deposits of Cu, Zn with byproduct Ag, Au
VSF	SEDIMENTARY AND FELSIC VOLCANIC ROCKS, undivided – rhyolite, quartz latite, and associated sediments	Favorable for deposits of Cu, Zn with byproduct Ag, Au
VSM	SEDIMENTARY AND MAFIC VOLCANIC ROCKS, undivided – basalt and associated sediments	Favorable for deposits of Cu, Zn with byproduct Ag and Au
SCB	CONTINENTAL SEDIMENTARY ROCKS – sandstone, shale and conglomerate, coal-bearing	Favorable for deposits of U with byproduct V
EPIGENETIC DEPOSITS		
Sedimentary Terranes		
SGS	GRAYWACKE AND SHALE – interbedded with minor volcanic rocks, favorable for mineral deposits introduced by metamorphic or epithermal processes	Favorable for deposits of Au, plus deposits like those of igneous terranes

Sources: AEIDC (1979); Hawley and AEIDC (1982); RDI et al. (1995)

1	=	Figures 26 through 29
Ag	=	silver
Au	=	gold
Co	=	cobalt
Cr	=	chromium
Cu	=	copper
Mo	=	molybdenum
Ni	=	nickel
Pb	=	lead
PGE	=	platinum group elements (e.g., platinum, palladium, iridium)
Pt	=	platinum
Sn	=	tin
REE	=	rare earth elements (e.g., lanthanum, cerium, neodymium)
U	=	uranium
V	=	vanadium
W	=	tungsten
Zn	=	zinc

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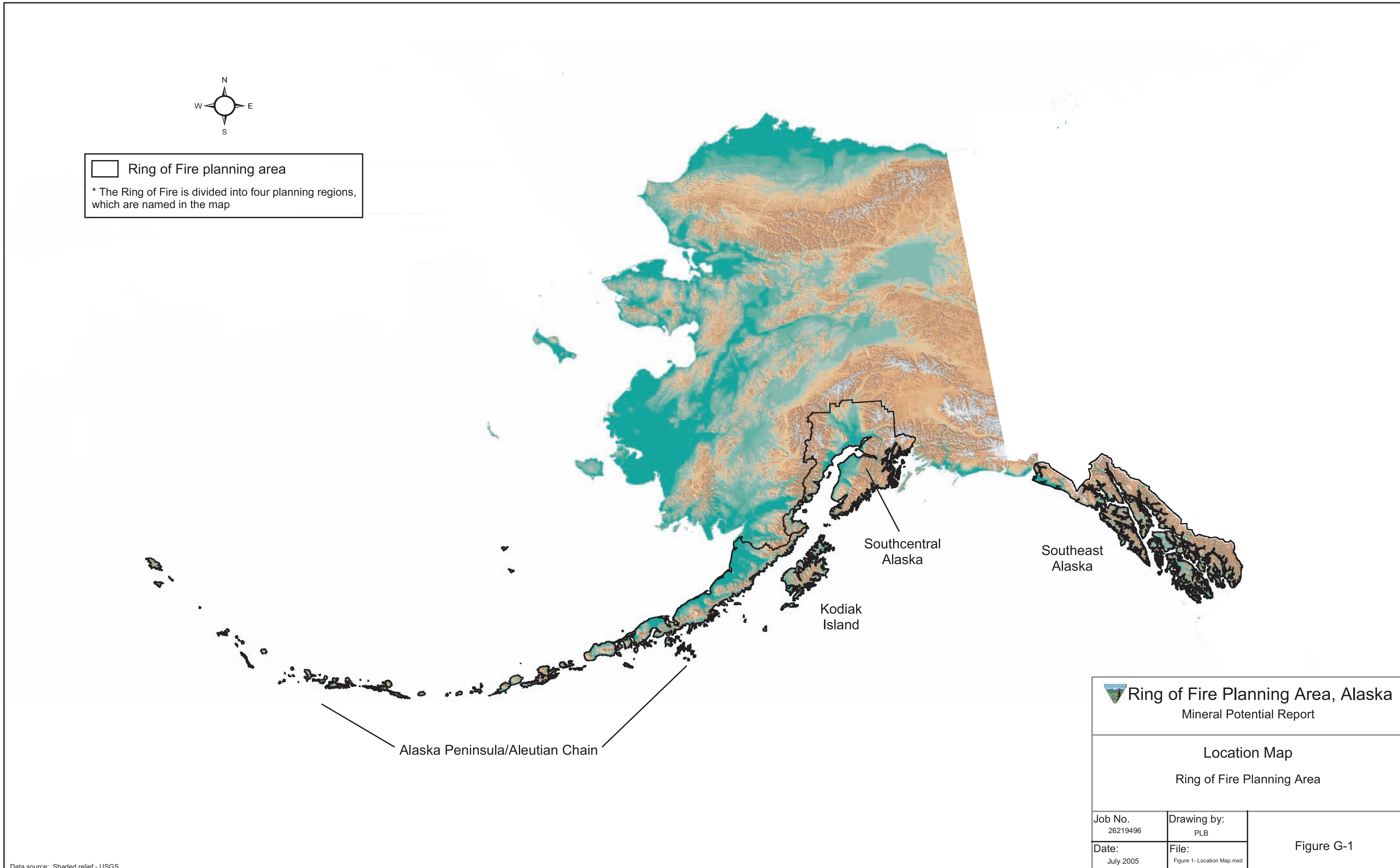
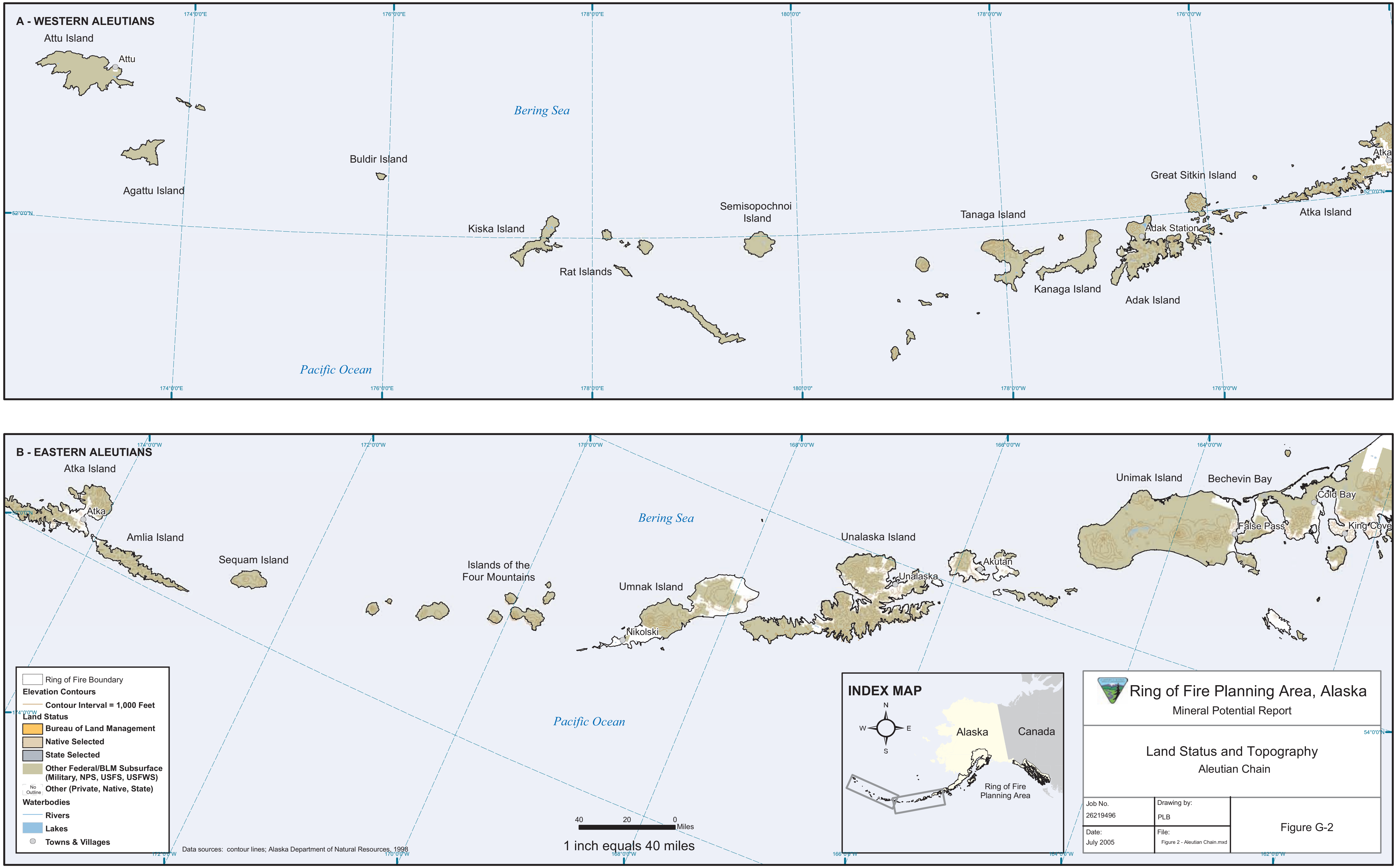
Figures



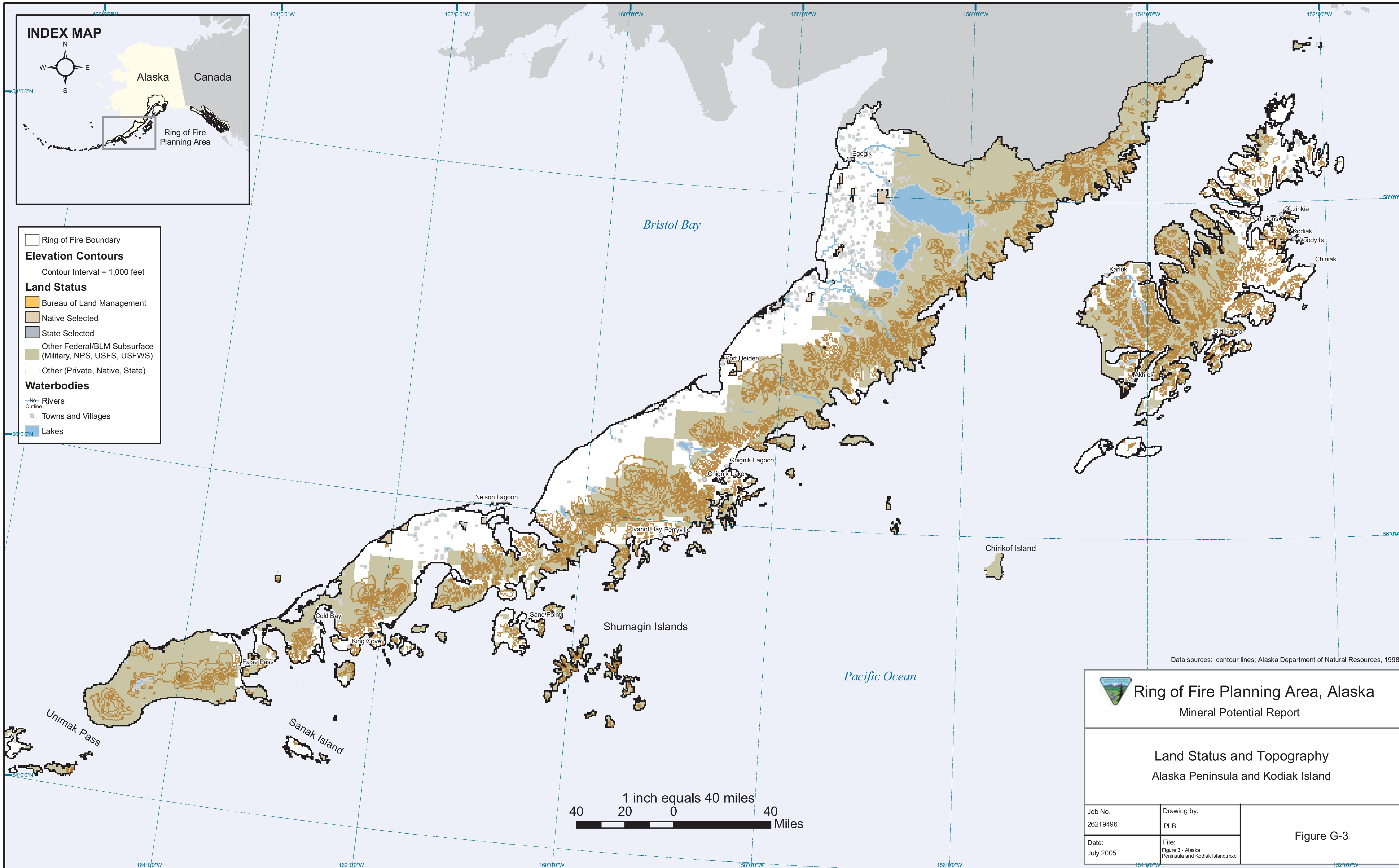
U.S. Geological Survey

Figure G-1, Location Map, Ring of Fire Planning Area



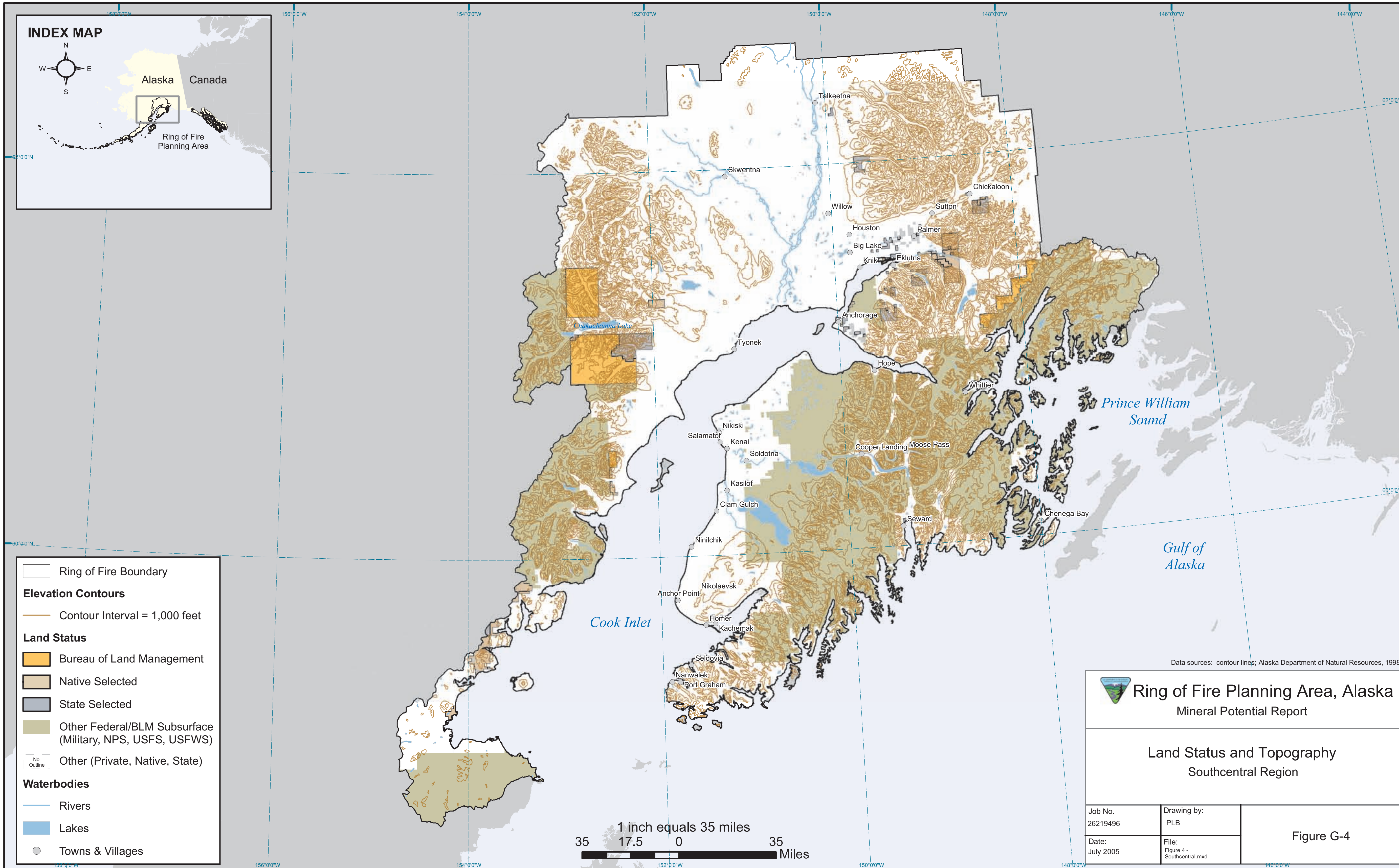
Bureau of Land Management

Figure G-2, Land Status and Topography of the Aleutian Chain



State of Alaska Department of Natural Resources

Figure G-3, Land Status and Topography of the Alaska Peninsula and Kodiak Island

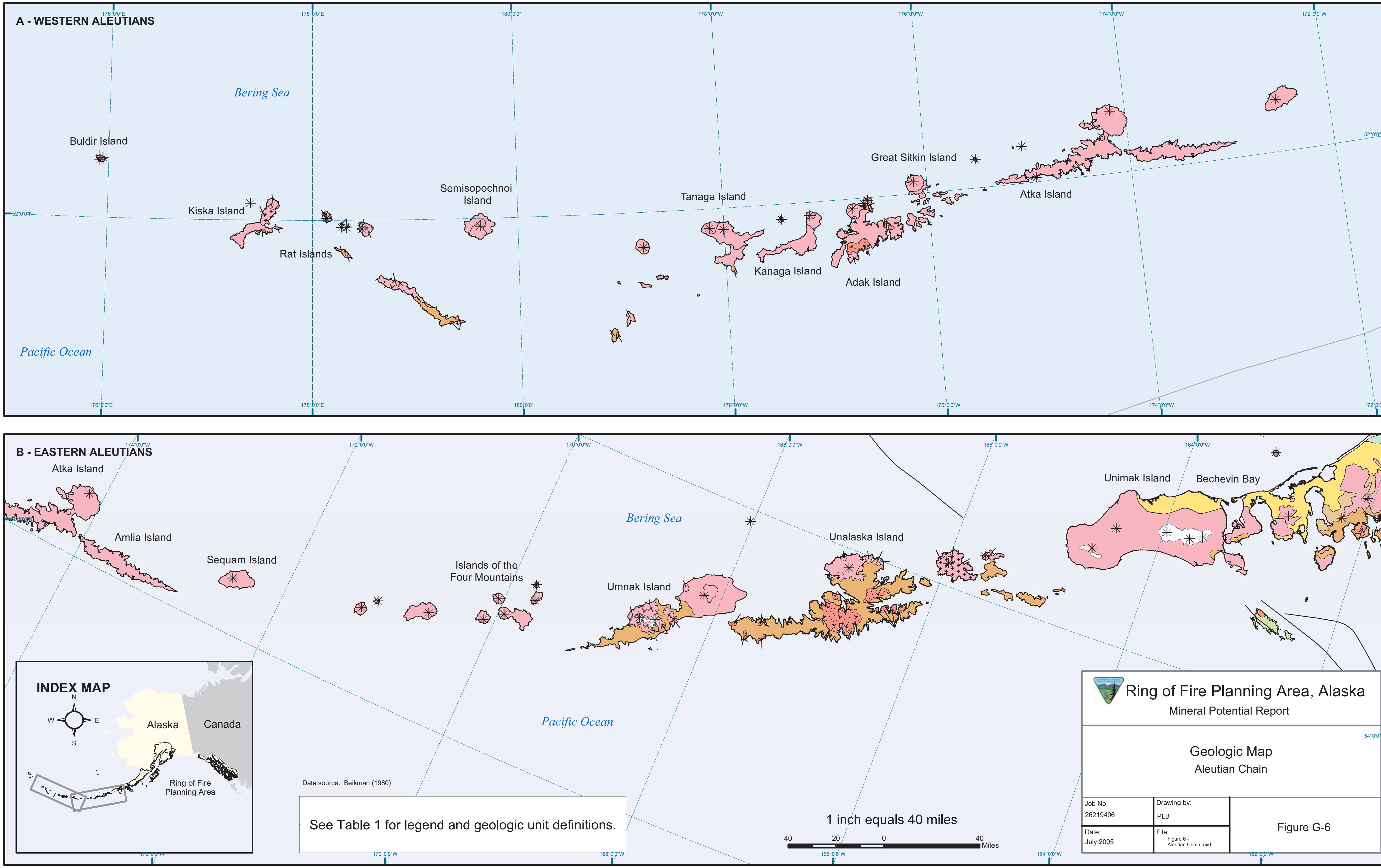


State of Alaska Department of Natural Resources

Figure G-4, Land Status and Topography of the Southcentral Region

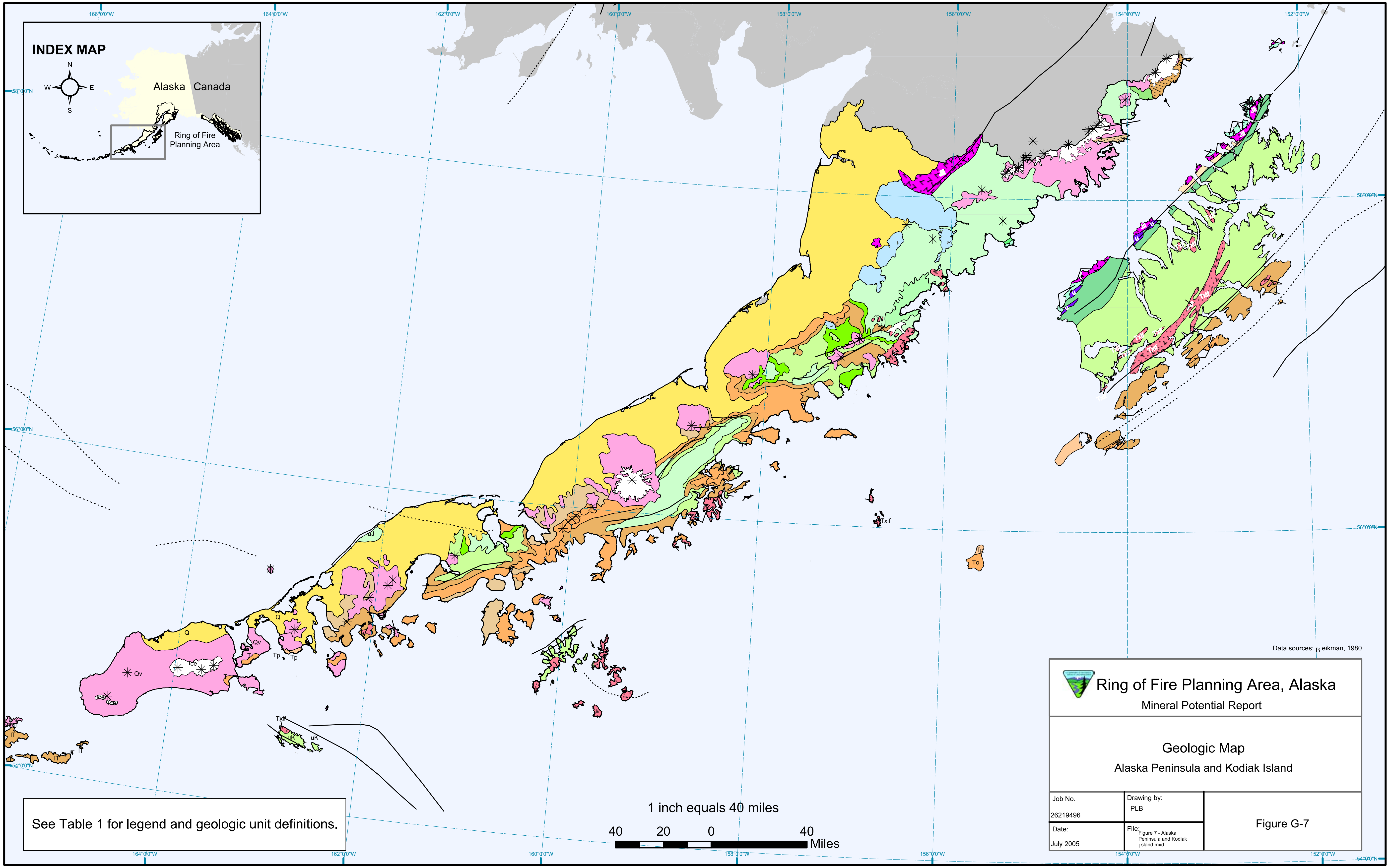
State of Alaska Department of Natural Resources

Figure G-5, Land Status and Topography of the Southeast Region



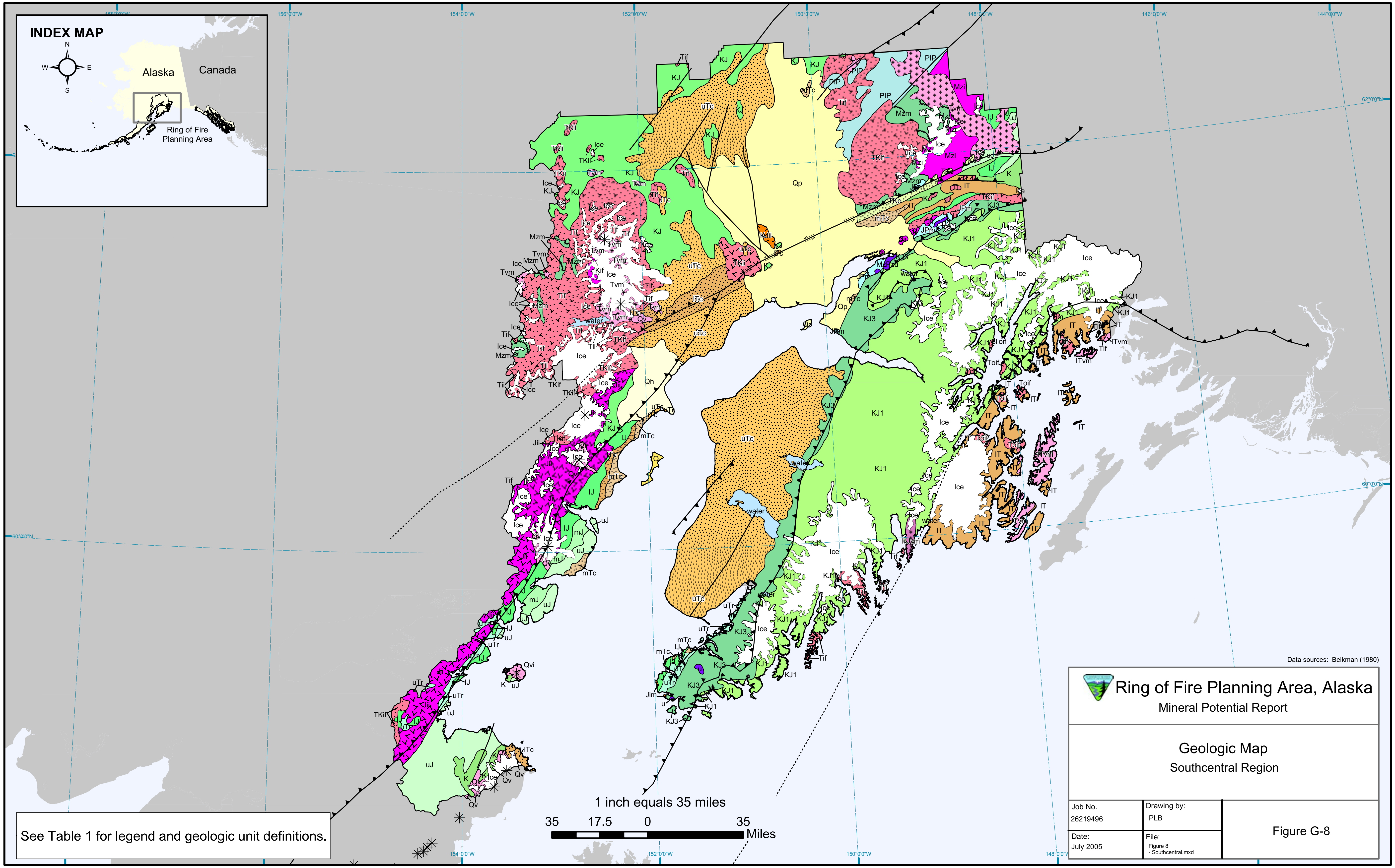
U.S. Geological Survey

Figure G-6, Geologic Map of the Aleutian Chain



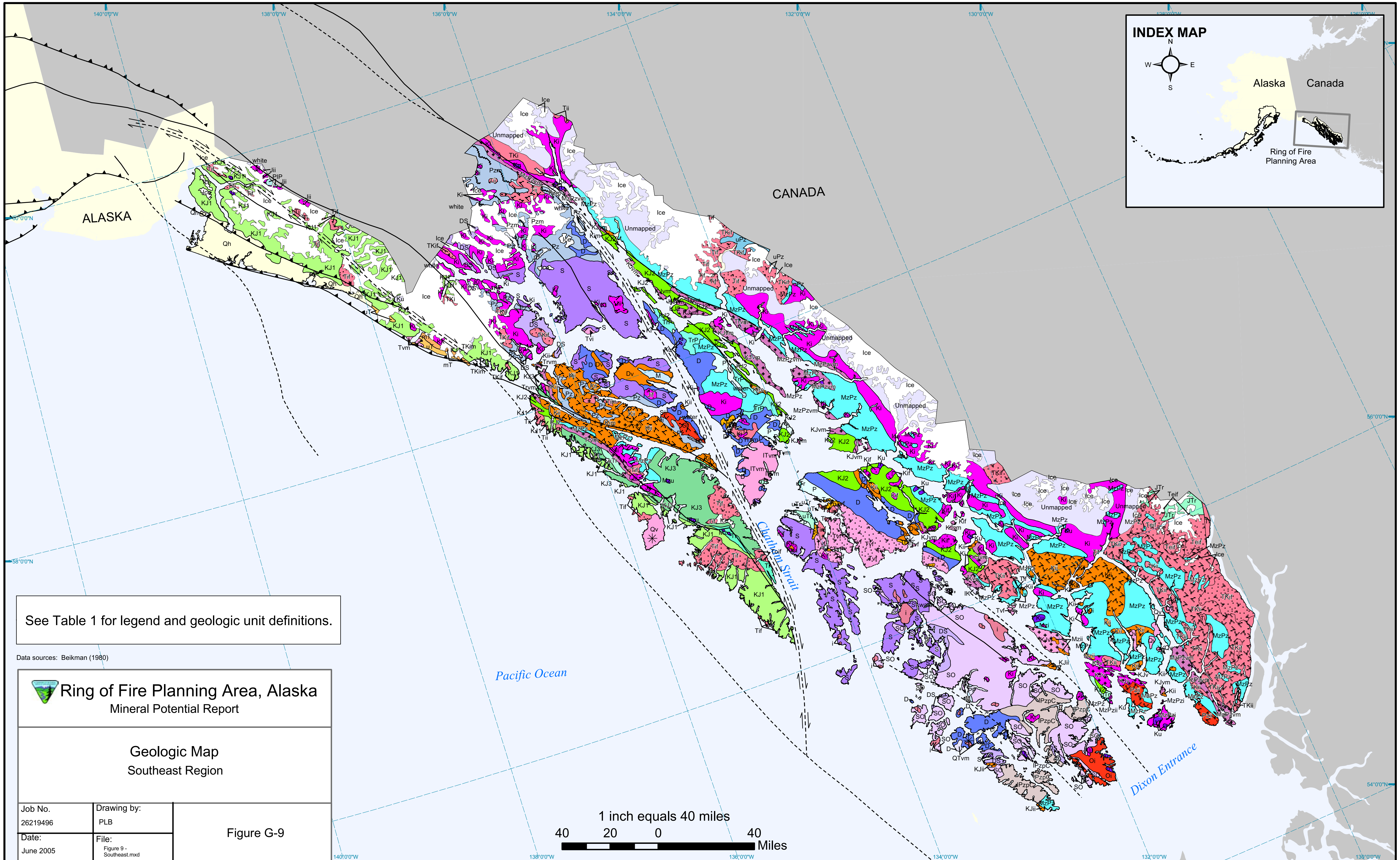
U.S. Geological Survey

Figure G-7, Geologic Map of the Alaska Peninsula and Kodiak Island



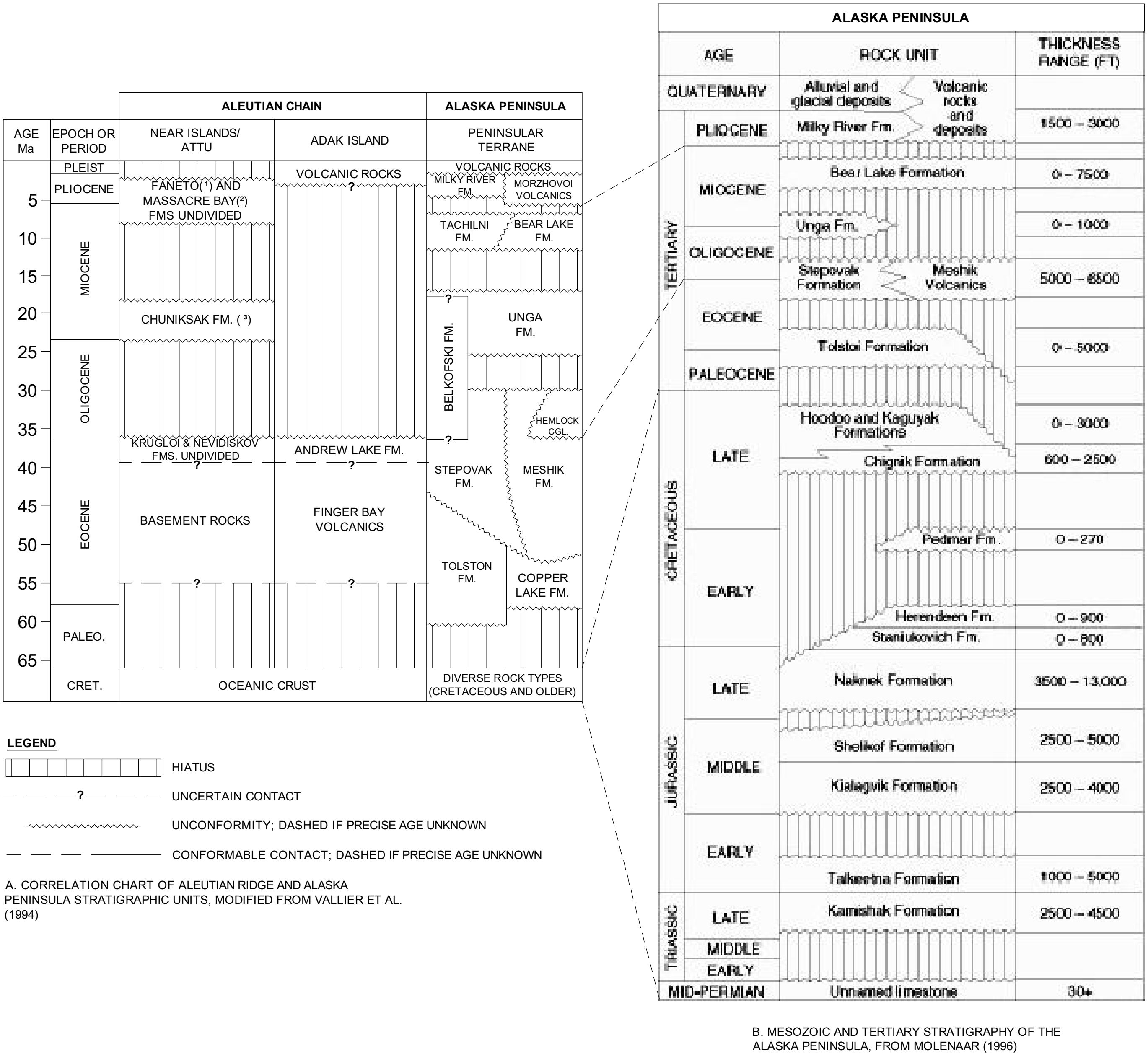
U.S. Geological Survey

Figure G-8, Geologic Map of the Southcentral Region



U.S. Geological Survey

Figure G-9, Geologic Map of the Southeast Region



Ring of Fire Planning Area, Alaska
Mineral Potential Report

Stratigraphic Columns
Aleutian Chain and Alaskan Peninsula

Job No.	Drawing by:	
26219496	ARN	Figure G-10
Date:	File:	
June 2004	Figs.dwg	

Figure G-10, Stratigraphic Columns, Aleutian Chain and Alaskan Peninsula

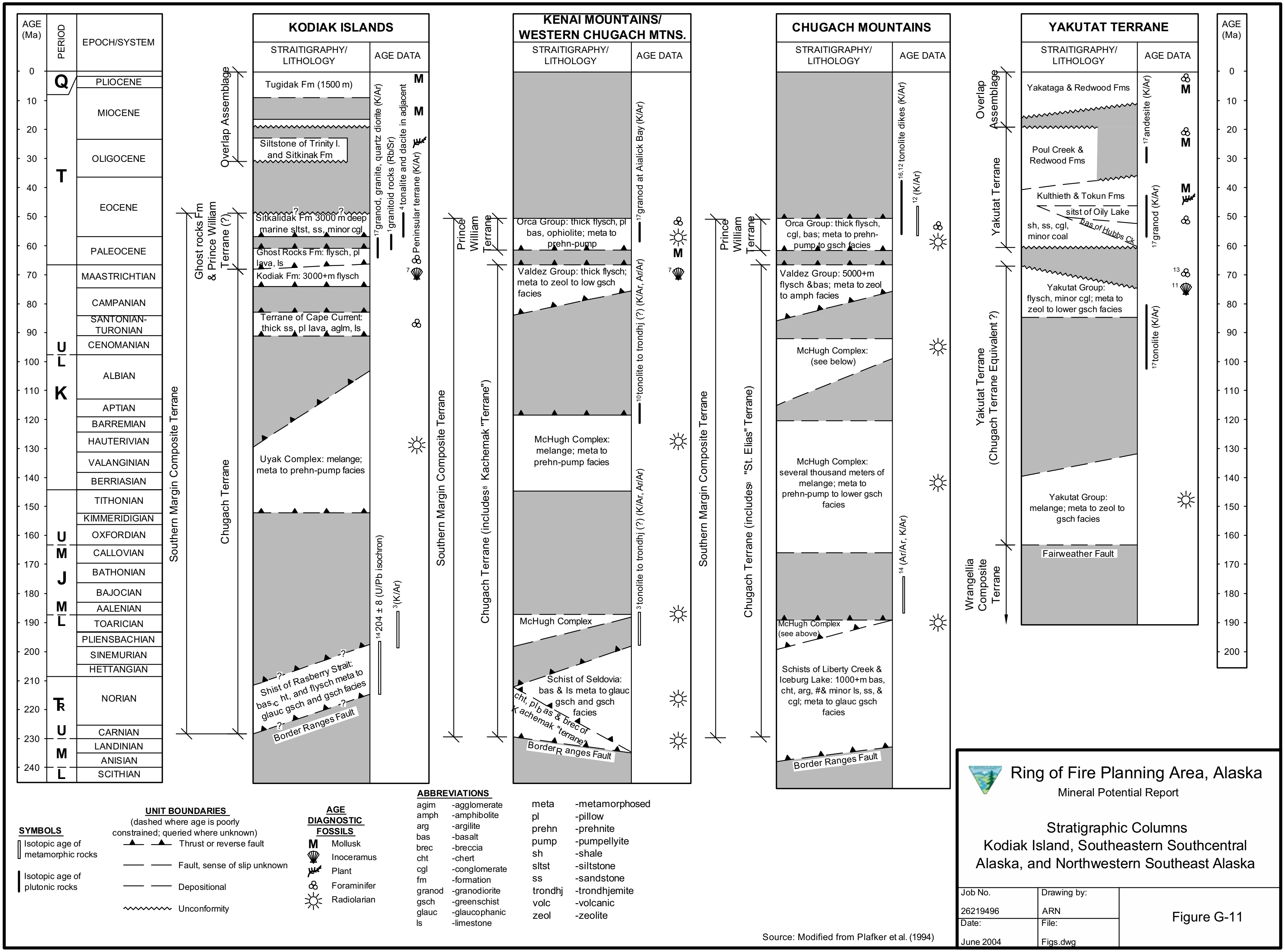
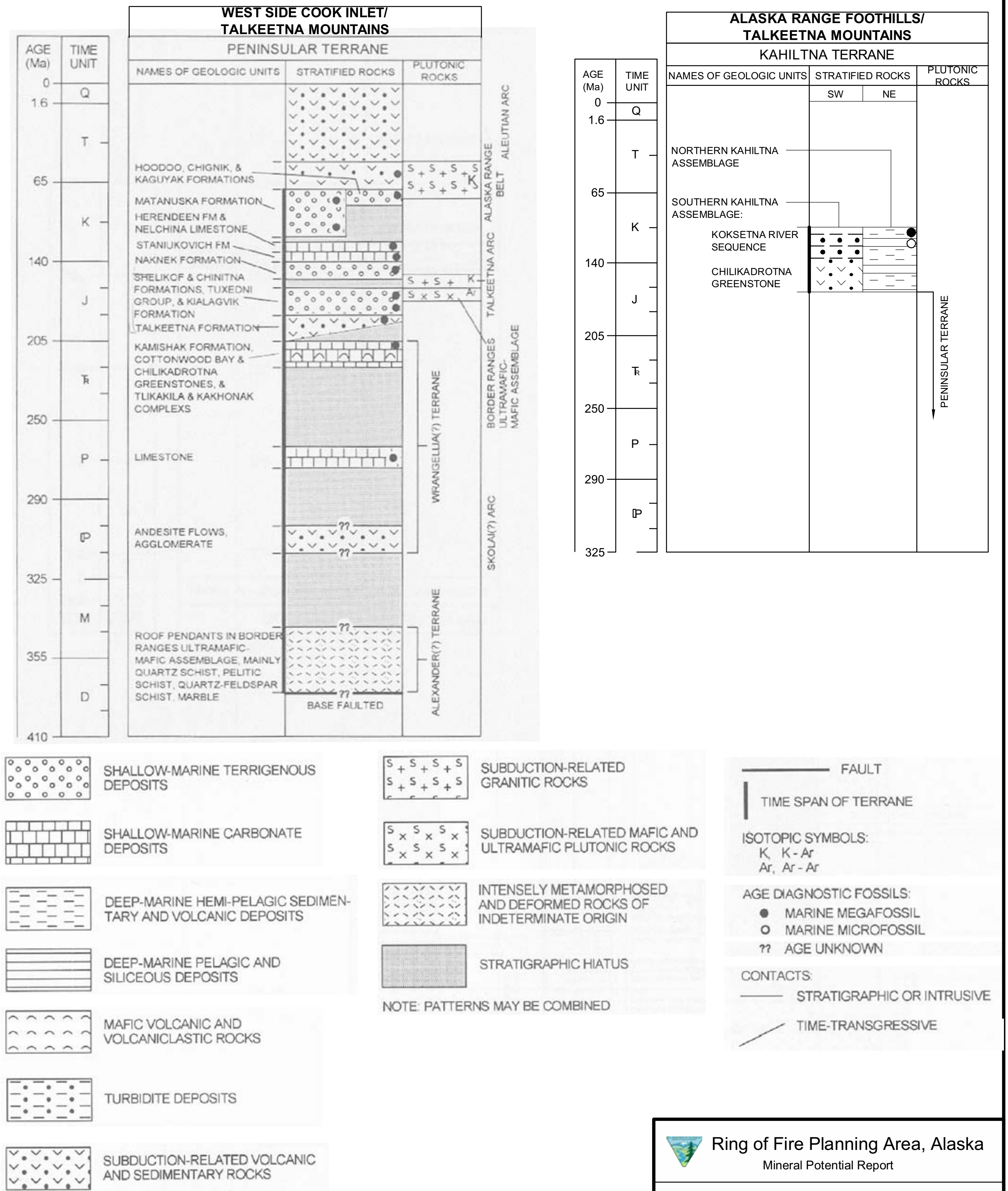


Figure G-11, Stratigraphic Columns, Kodiak Island, Southeastern Southcentral Alaska, and Northwestern Southeast Alaska



Ring of Fire Planning Area, Alaska
Mineral Potential Report

Stratigraphic Columns
Western and Northern Southcentral Alaska

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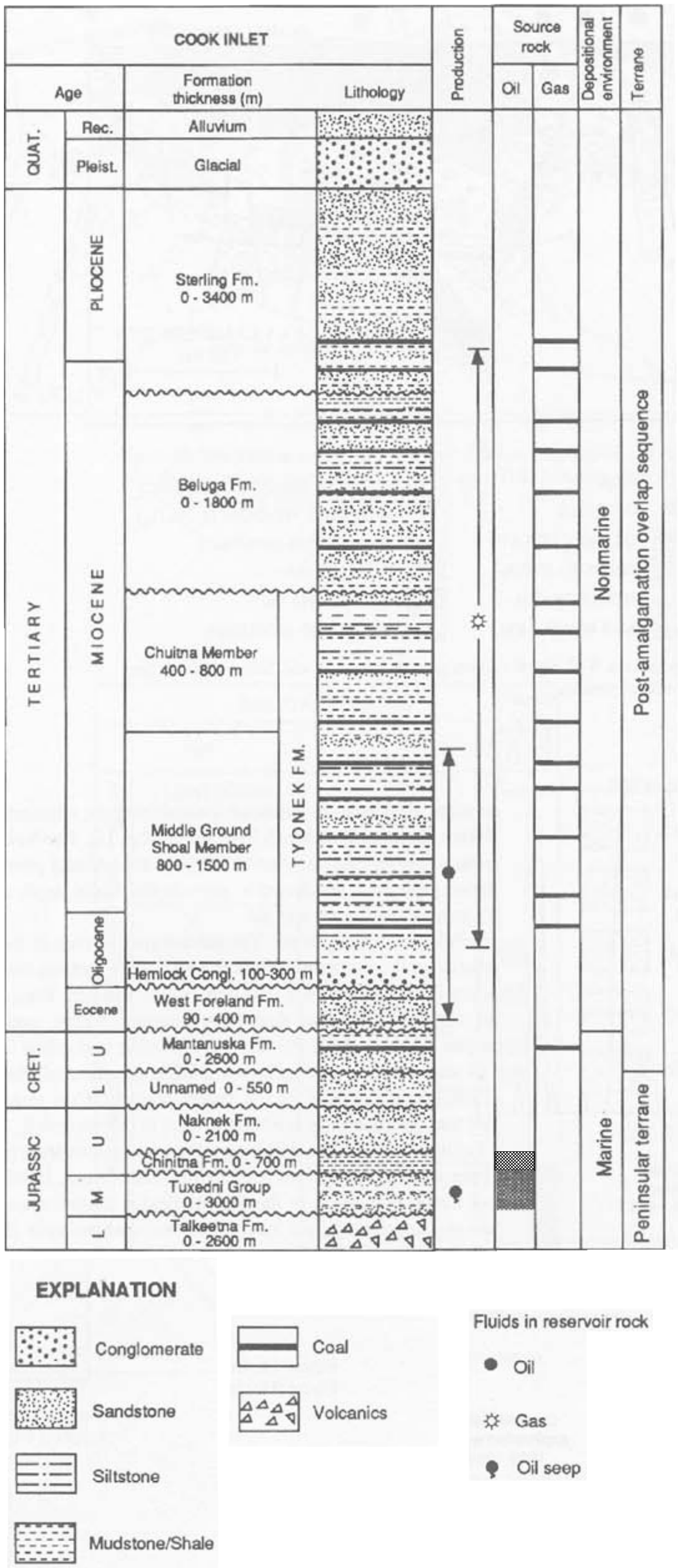
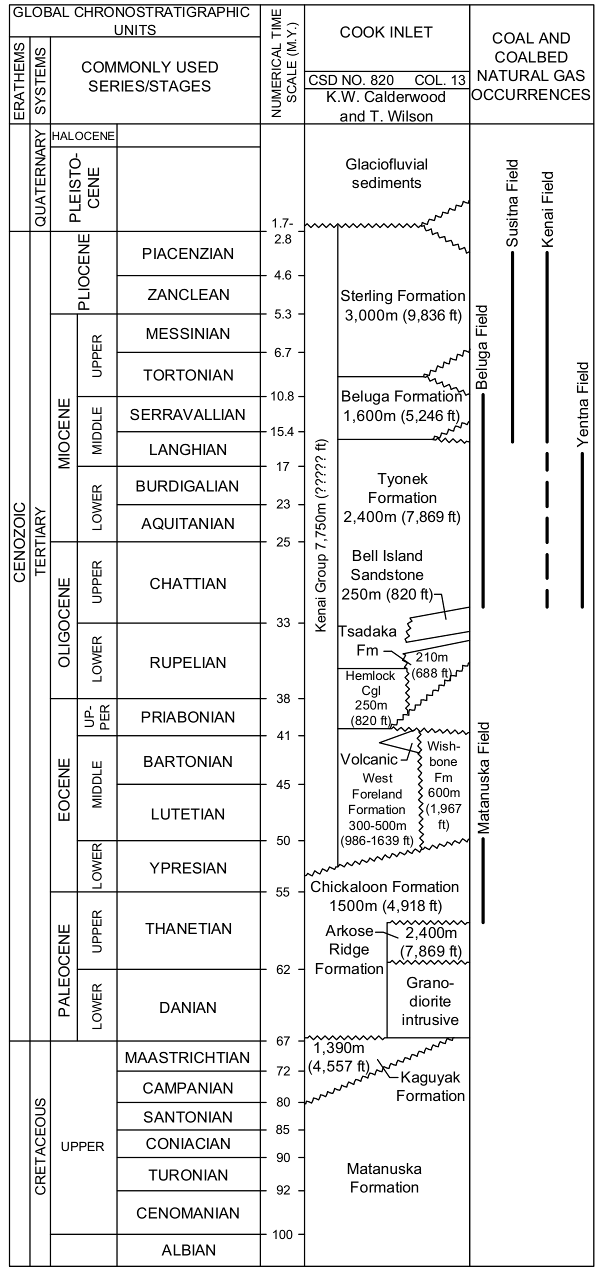
Date: June 2004	File: Figs.dwg	

Figure G-12, Stratigraphic Columns, Western and Northern Southcentral Alaska



A. Generalized stratigraphic column for Cook Inlet showing petroleum in reservoir rocks and source rock intervals. See Table 2 for oil and gas field names. Modified from Magoon (1994,1996a)



B. Stratigraphic column of Cook Inlet-Susitna basin showing coal and coalbed natural gas occurrences and fields. Modified from Wahrhaftig (1994) and Merritt and Hawley (1986)

Ring of Fire Planning Area, Alaska
Mineral Potential Report

Stratigraphic Columns
Cook Inlet-Susitna Basin

Job No.	Drawing by:	
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Date:	File:	
June 2004	Figs.dwg	

Figure G-13, Stratigraphic Columns, Cook Inlet-Susitna Basin

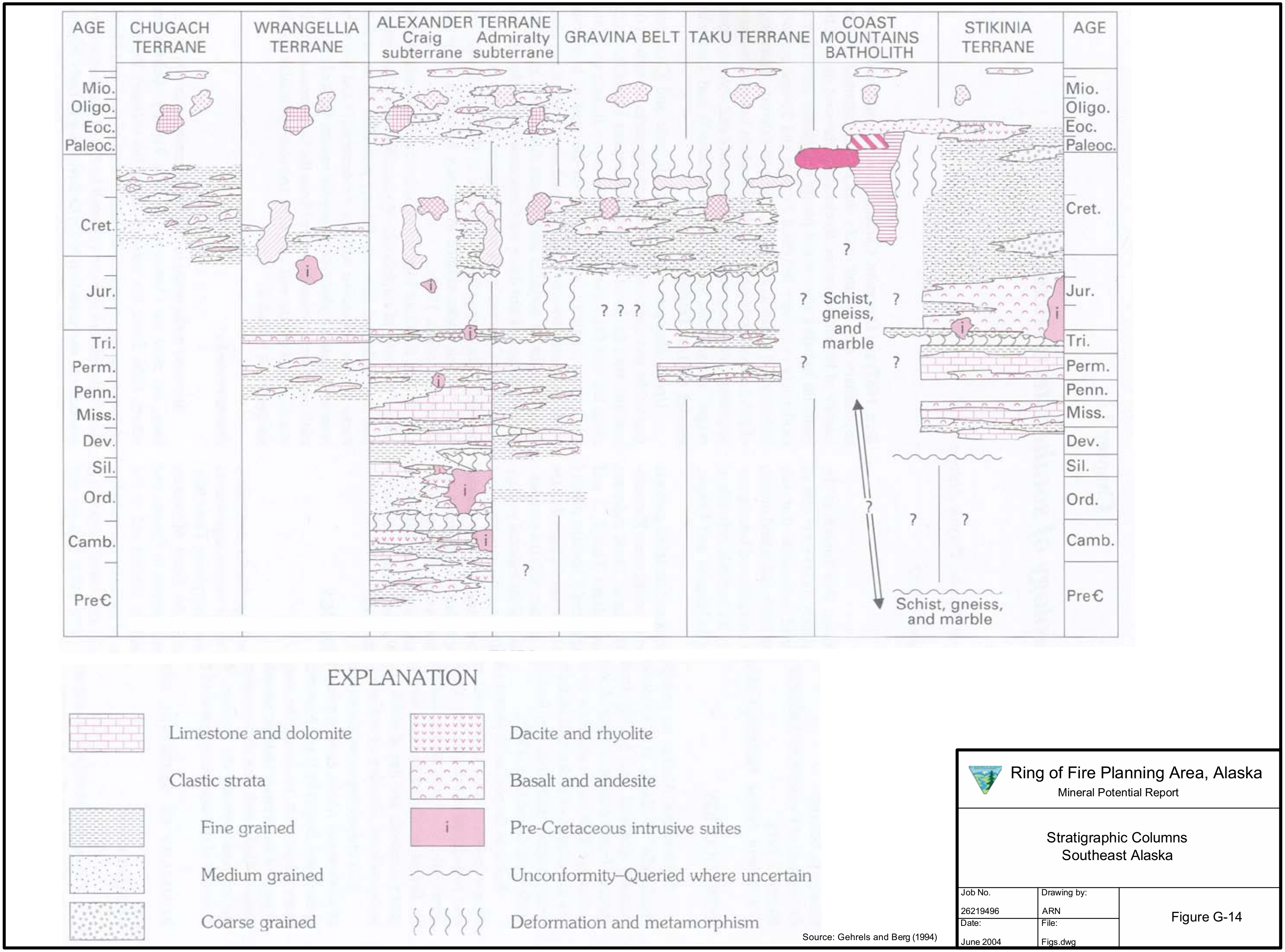

Figure G-14, Stratigraphic Columns, Southeast Alaska

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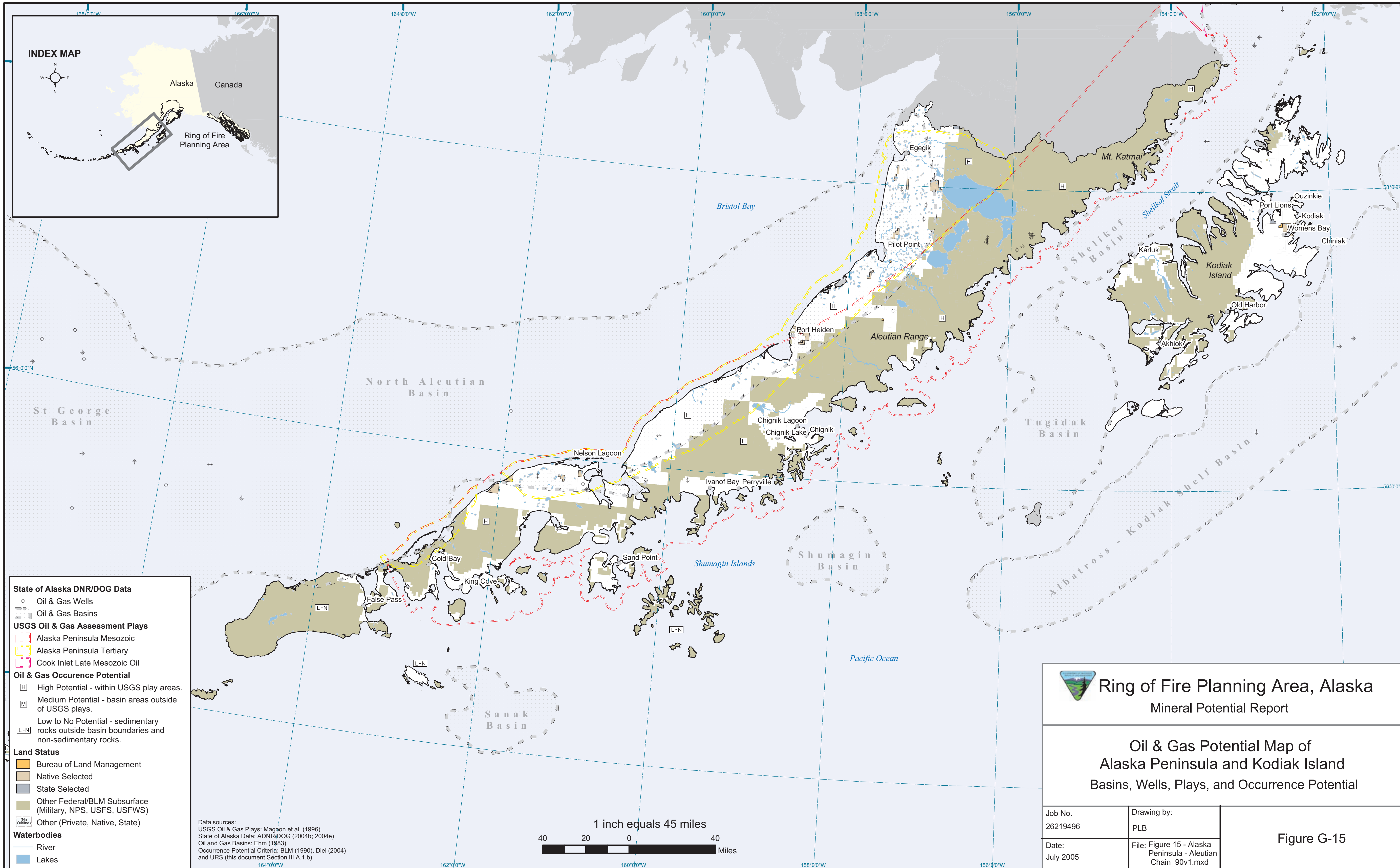

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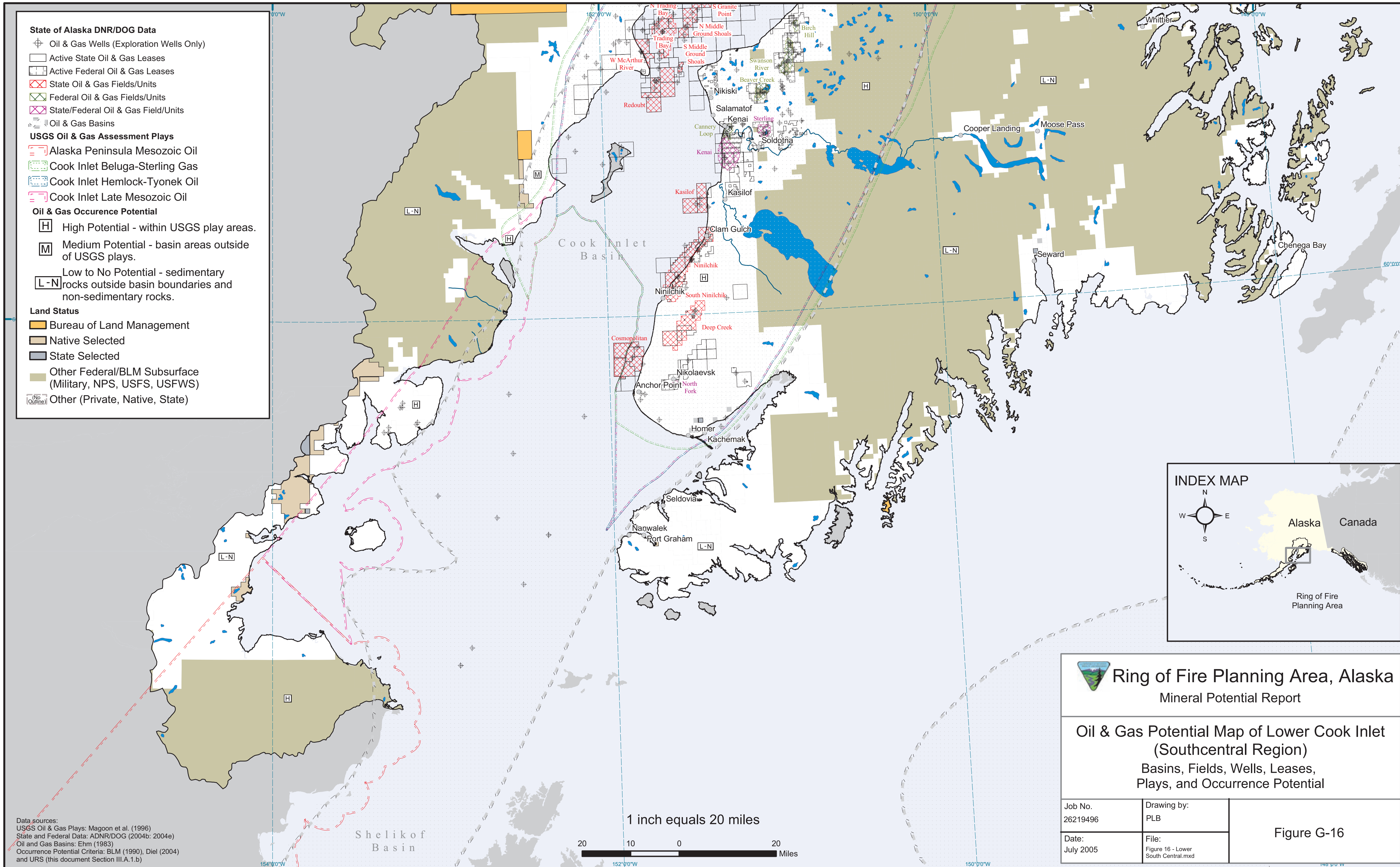
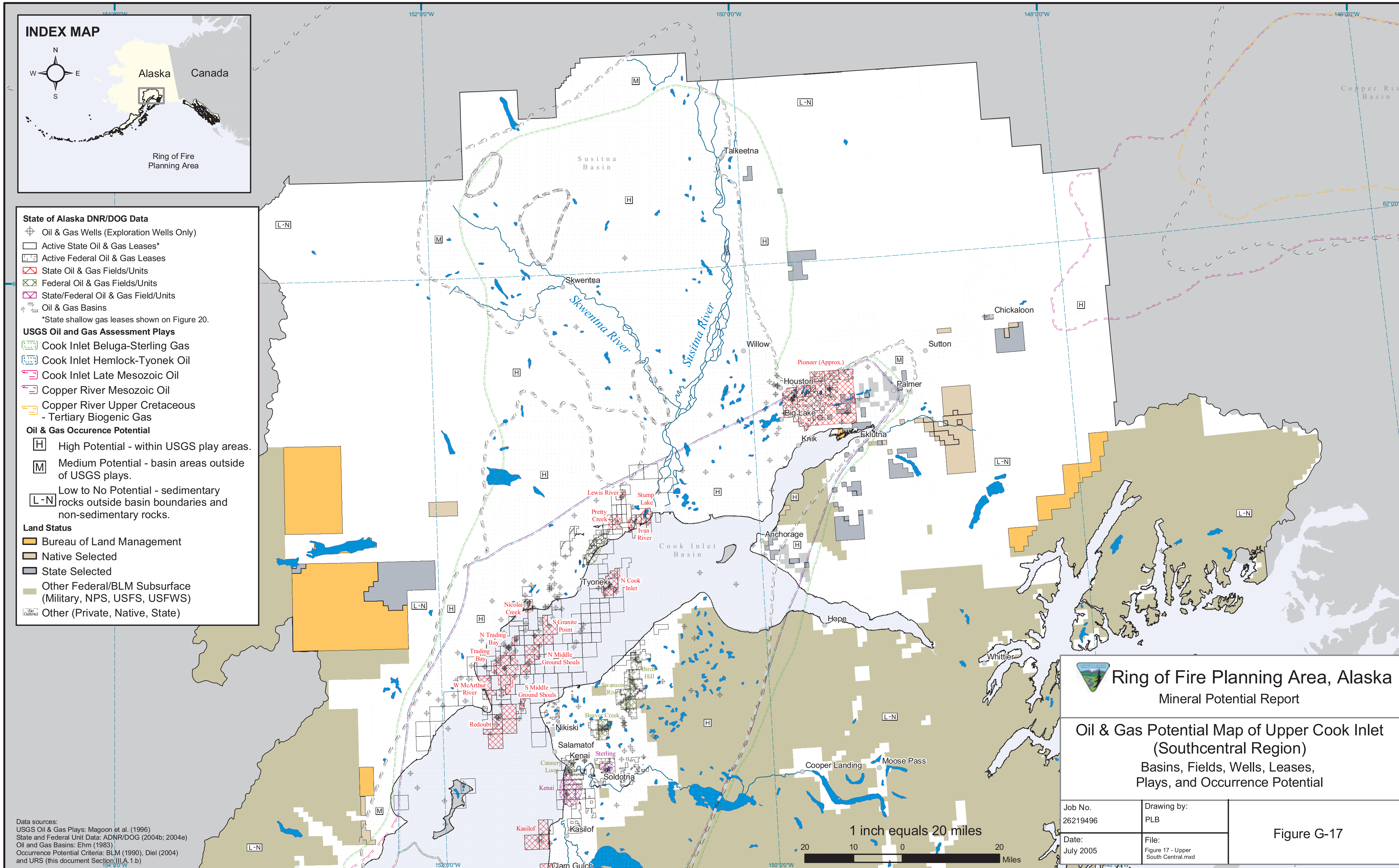
Figure G-15, Oil & Gas Potential Map of Alaska Peninsula and Kodiak Island



Bureau of Land Management

Figure G-16, Oil & Gas Potential Map of Lower Cook Inlet (Southcentral Region)



Bureau of Land Management

Figure G-17, Oil & Gas Potential Map of Upper Cook Inlet (Southcentral Region)

Bureau of Land Management

Figure G-18, Oil and Gas Potential Map of the Southeast Region

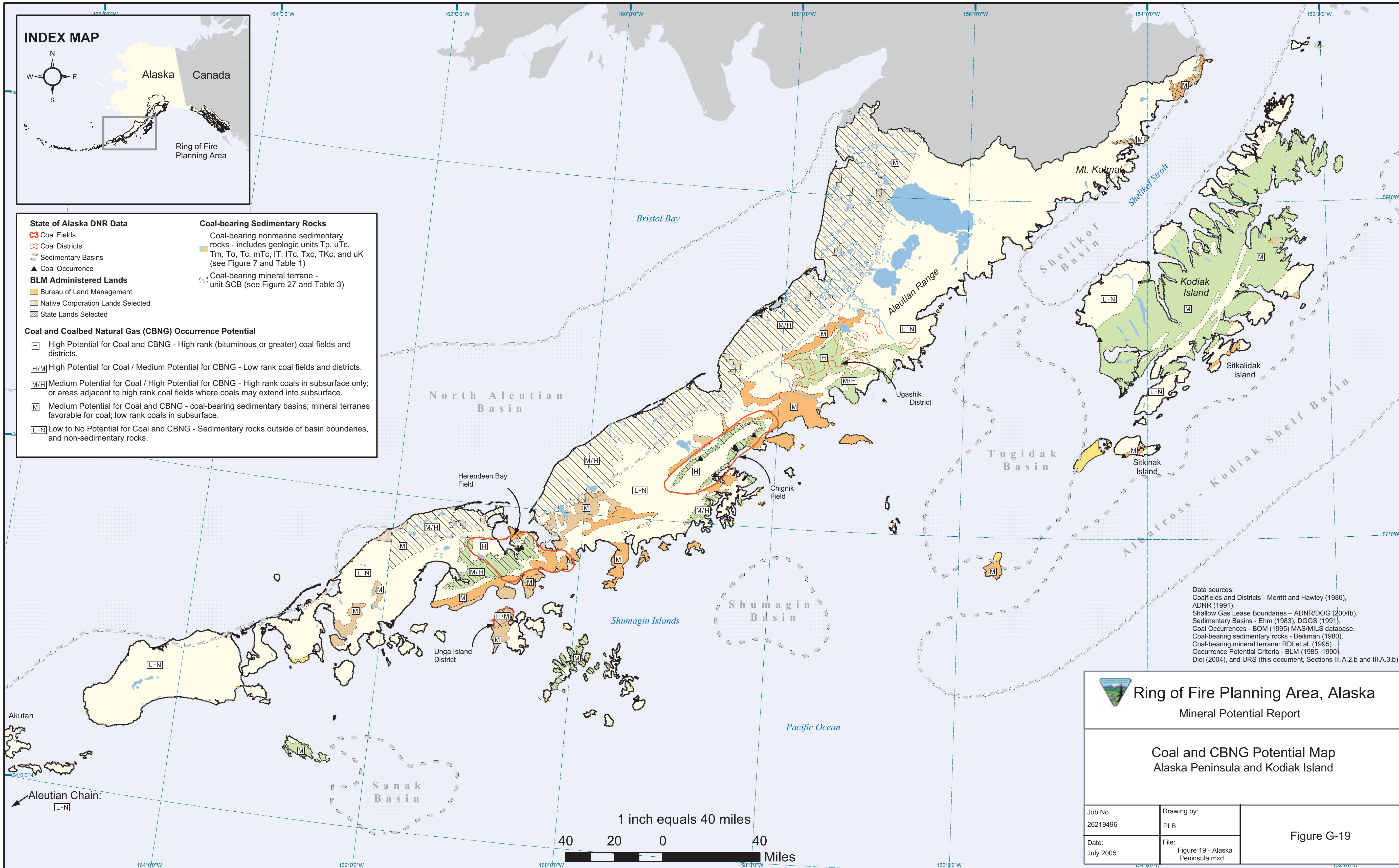


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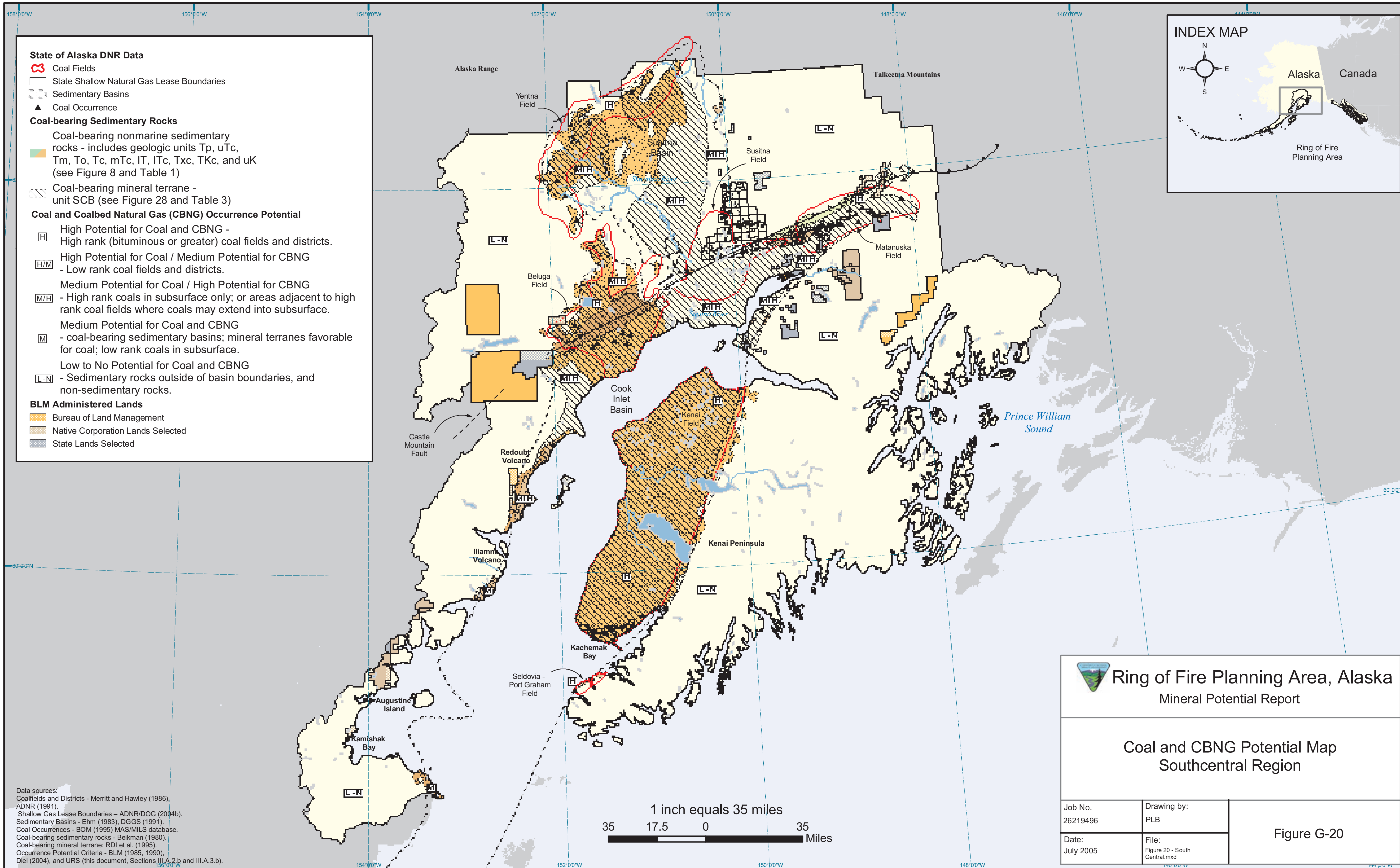
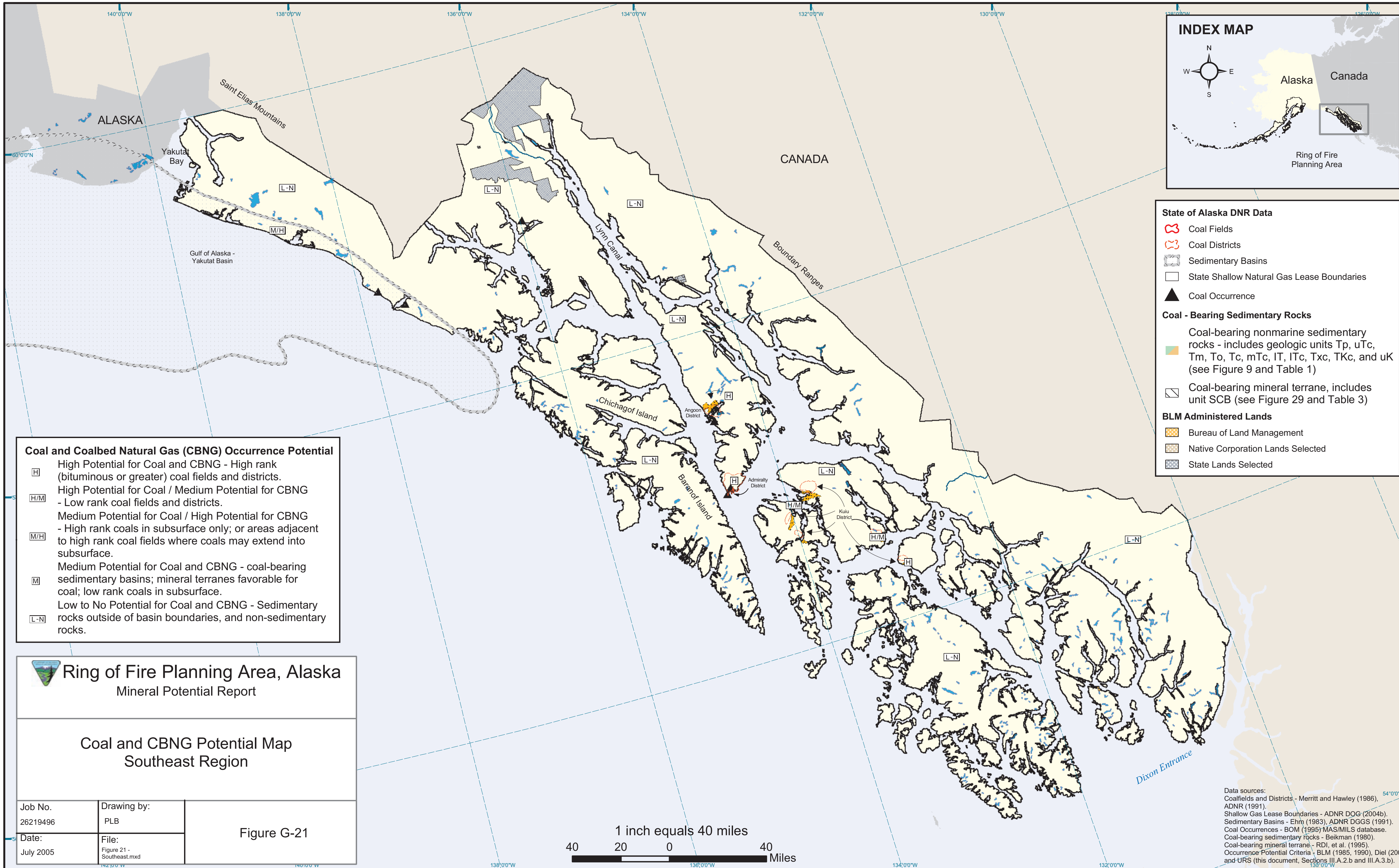
Figure G-19, Coal and CBNG Potential Map of Alaska Peninsula and Kodiak Island



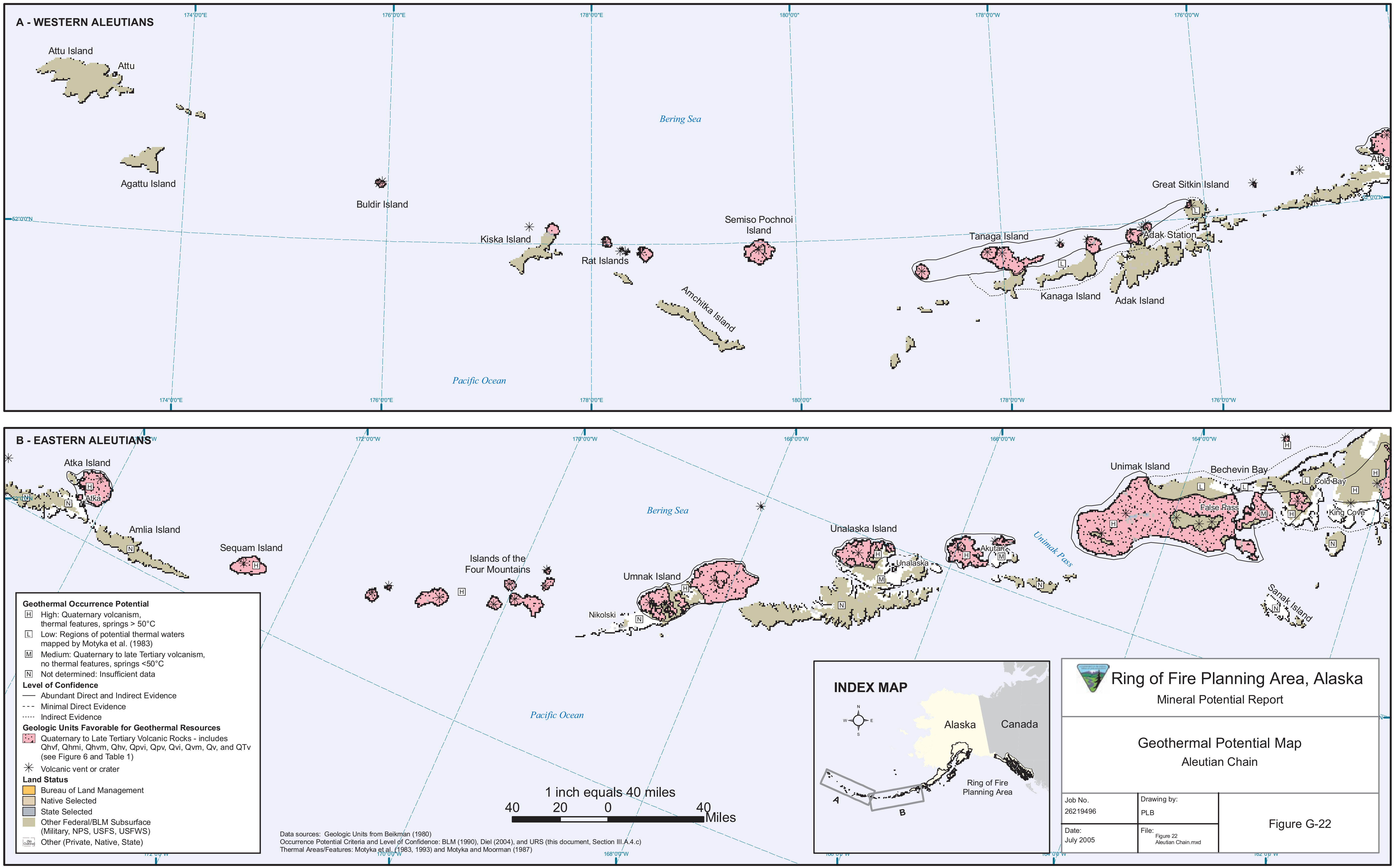
Bureau of Land Management

Figure G-20, Coal and CBNG Potential Map, Southcentral Region



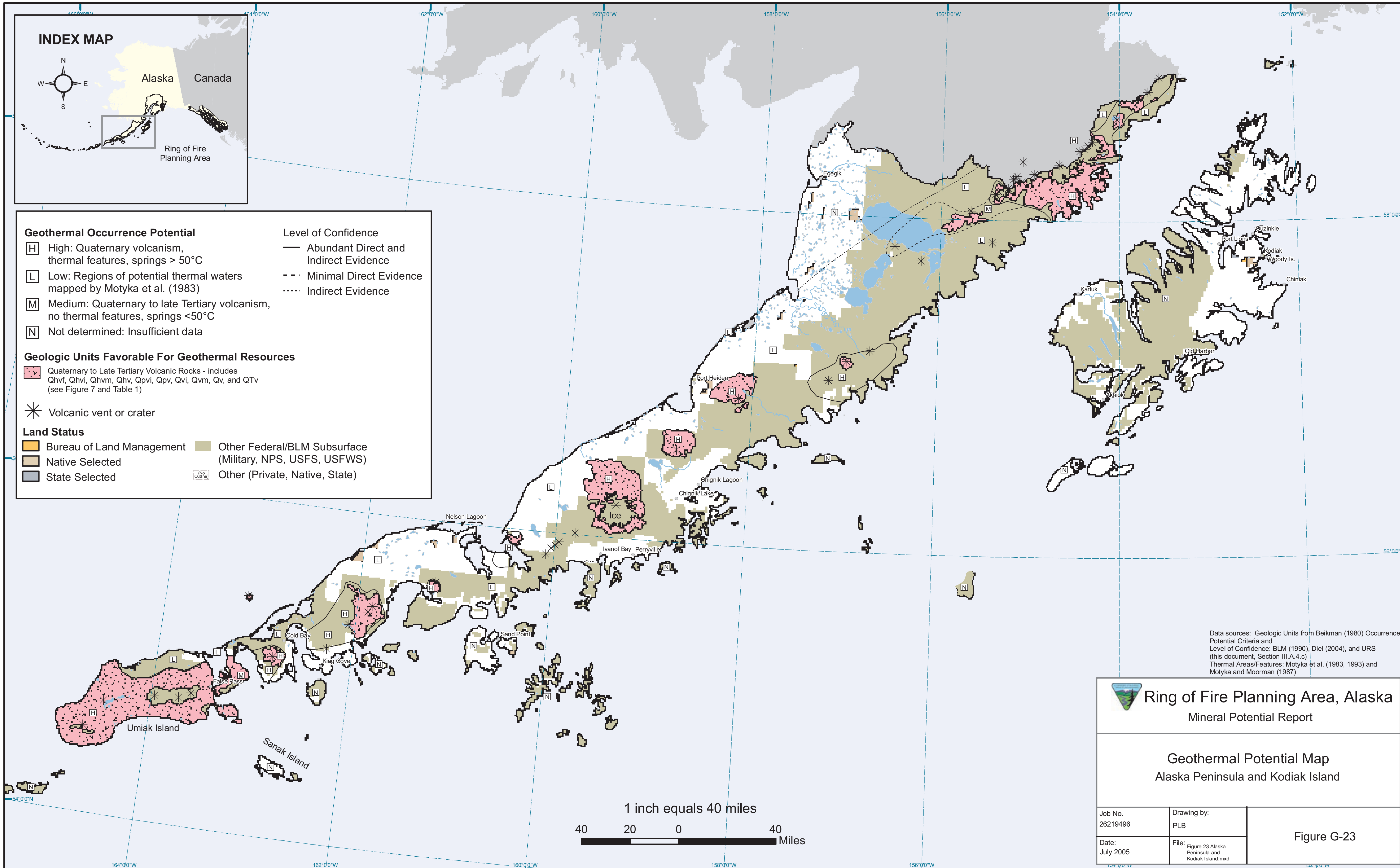
Bureau of Land Management

Figure G-21, Coal and CBNG Potential Map, Southeast Region



Bureau of Land Management

Figure G-22, Geothermal Potential Map, Aleutian Chain



Bureau of Land Management

Figure G-23, Geothermal Potential Map, Alaska Peninsula and Kodiak Island

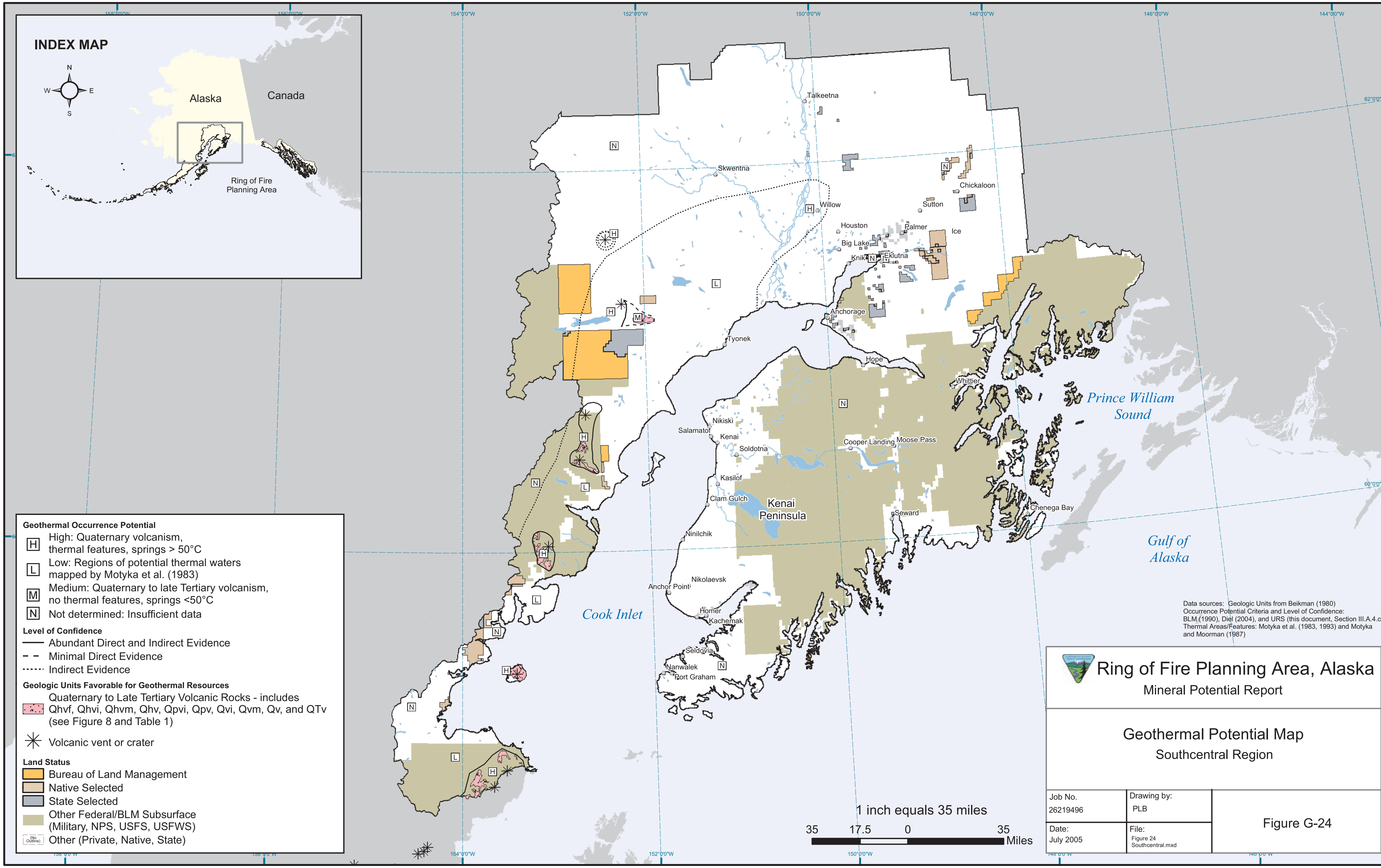


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Figure G-24, Geothermal Potential Map, Southcentral Region

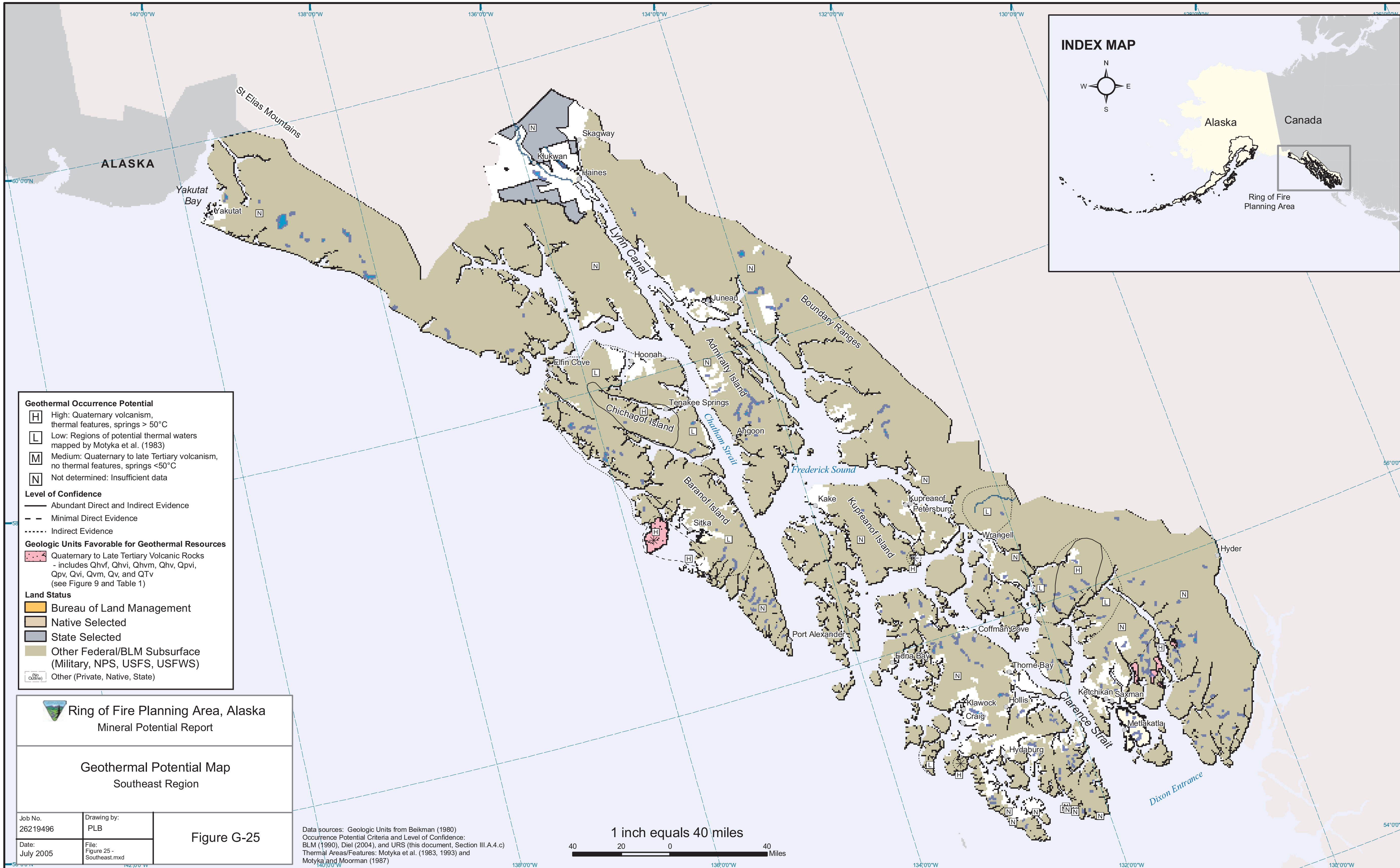

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Figure G-25, Geothermal Potential Map, Southeast Region

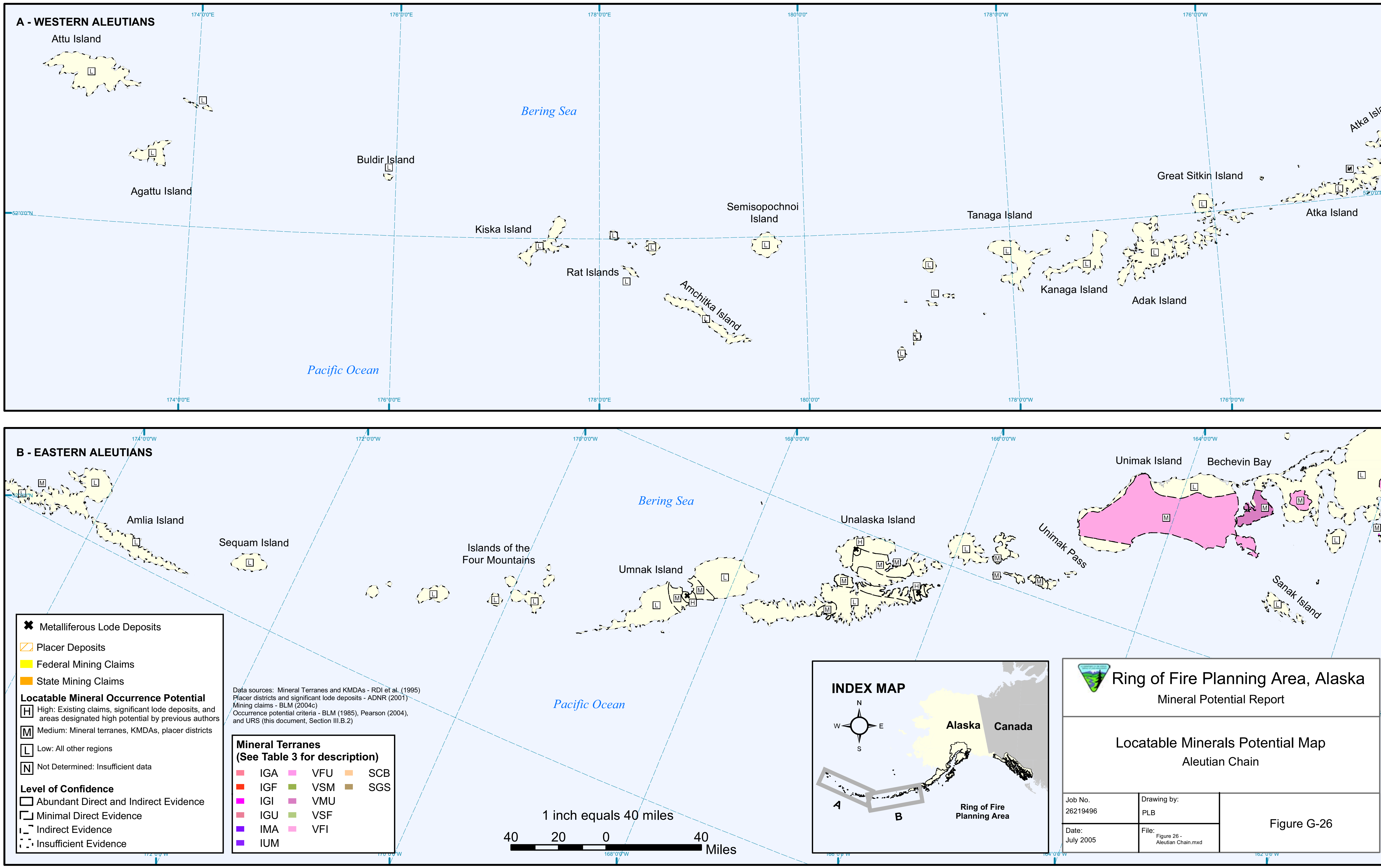

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Figure G-26, Locatable Minerals Potential Map, Aleutian Chain

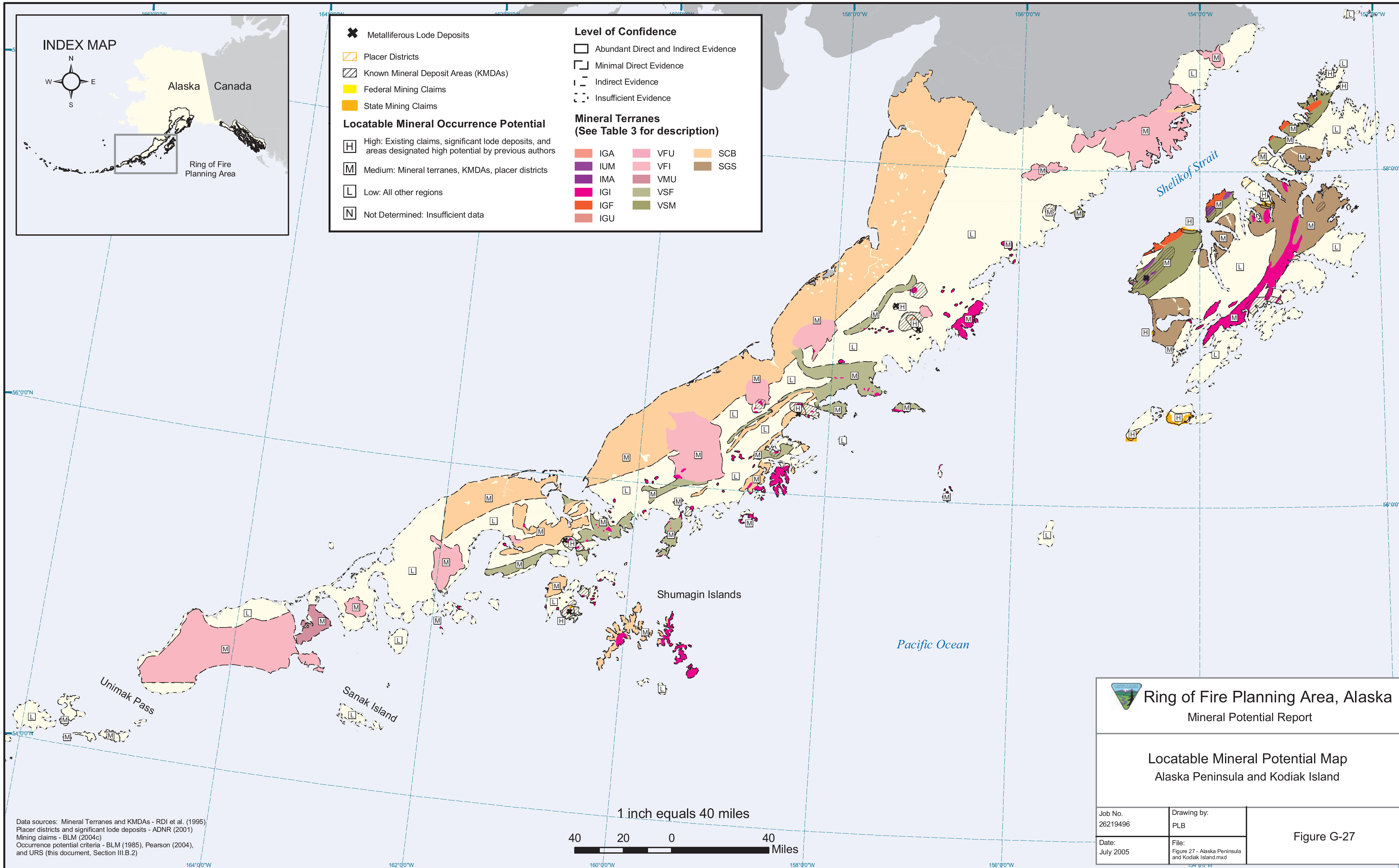

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Figure G-27, Locatable Mineral Potential Map, Alaska Peninsula and Kodiak Island

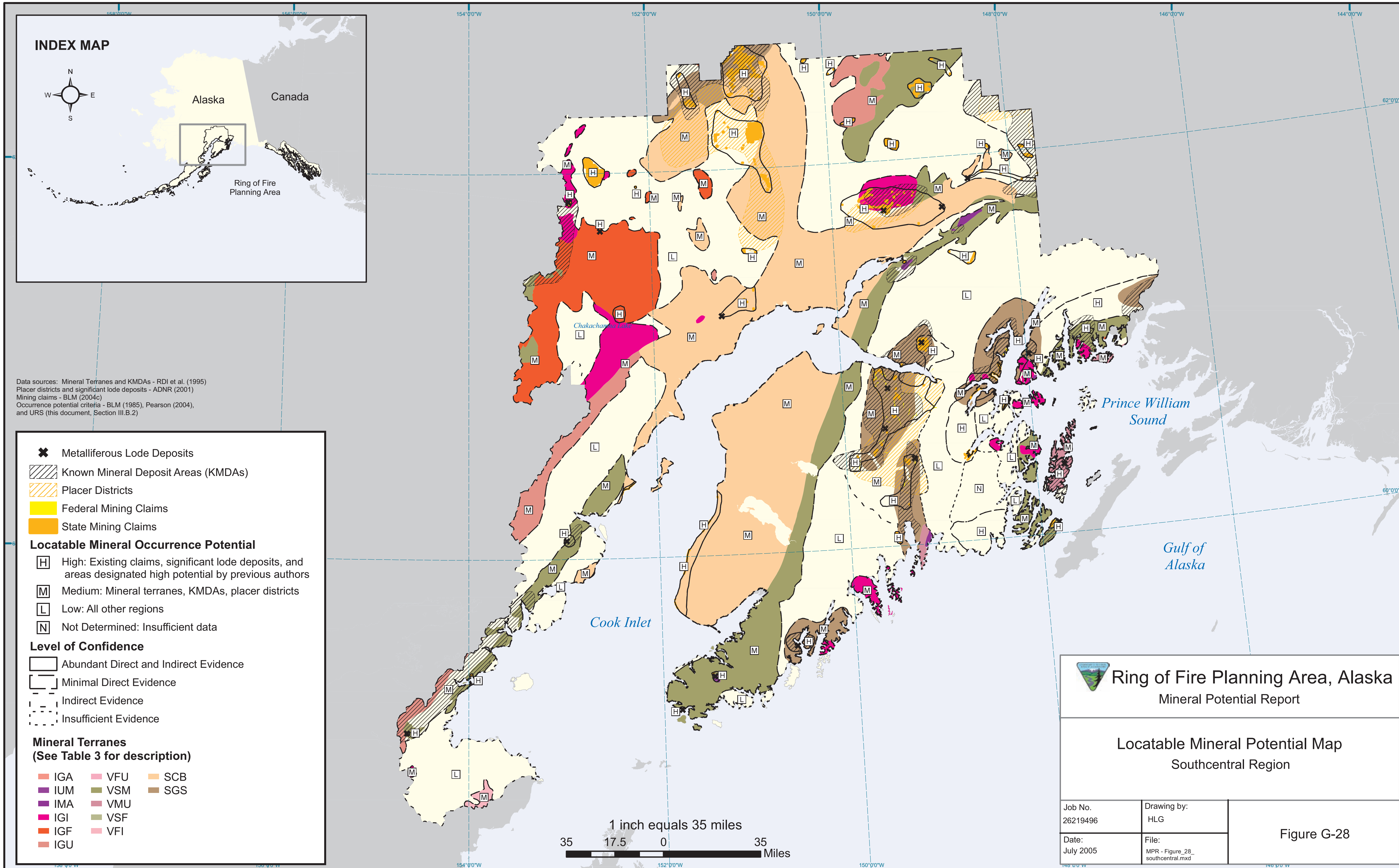

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Figure G-28, Locatable Mineral Potential Map, Southcentral Region

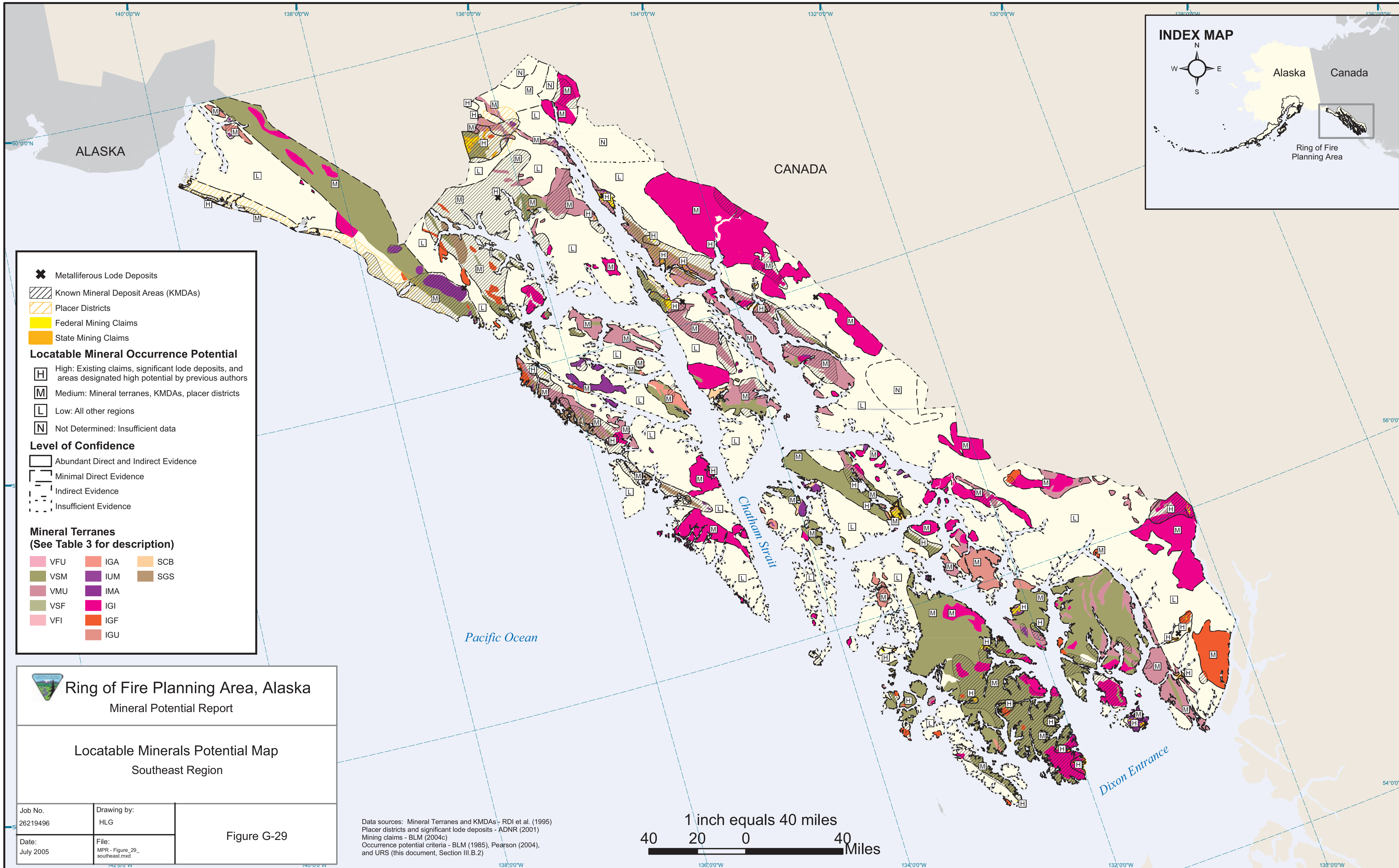

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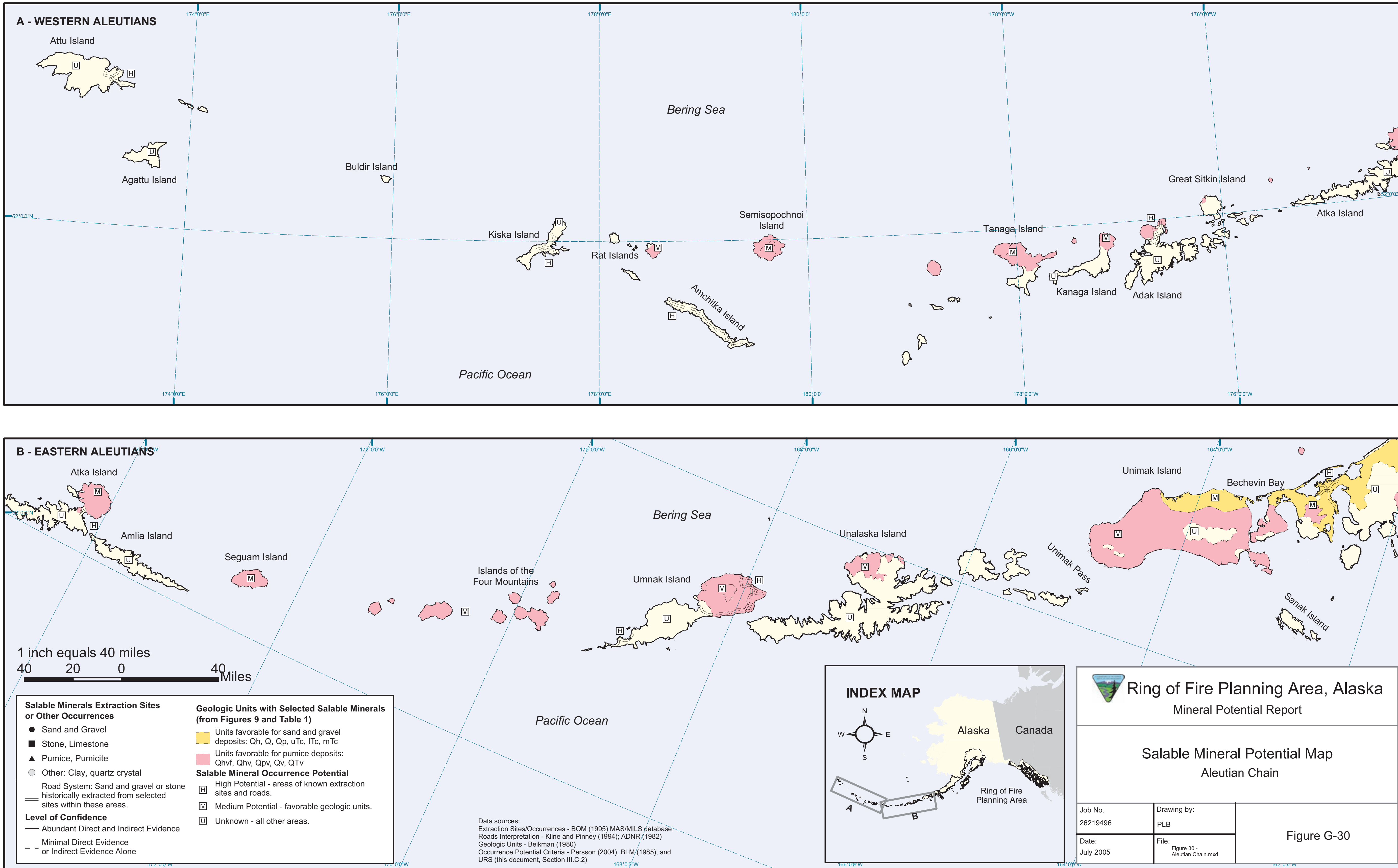
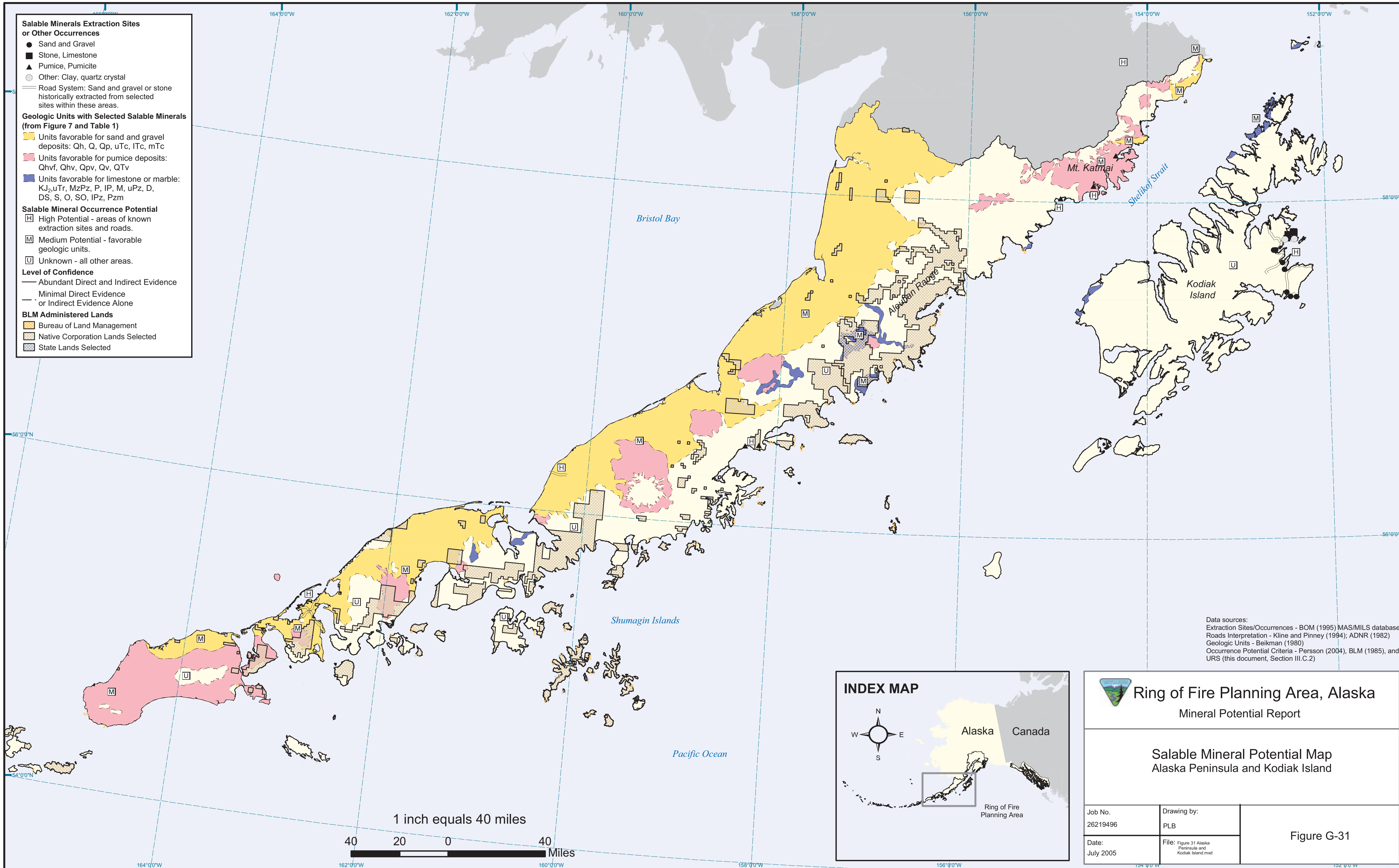
Figure G-29, Locatable Minerals Potential Map, Southeast Region



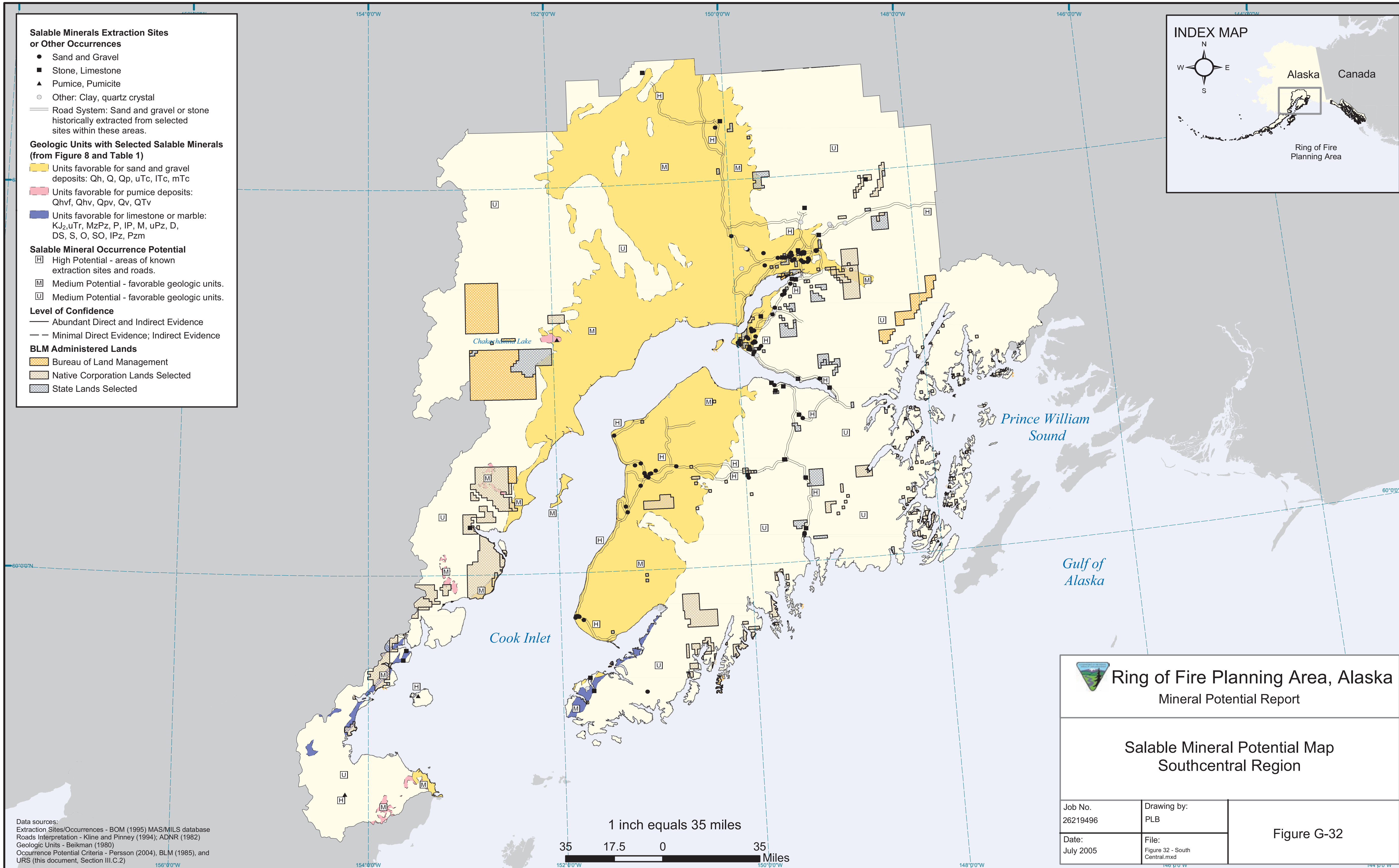
Bureau of Land Management

Figure G-30, Salable Mineral Potential Map, Aleutian Chain



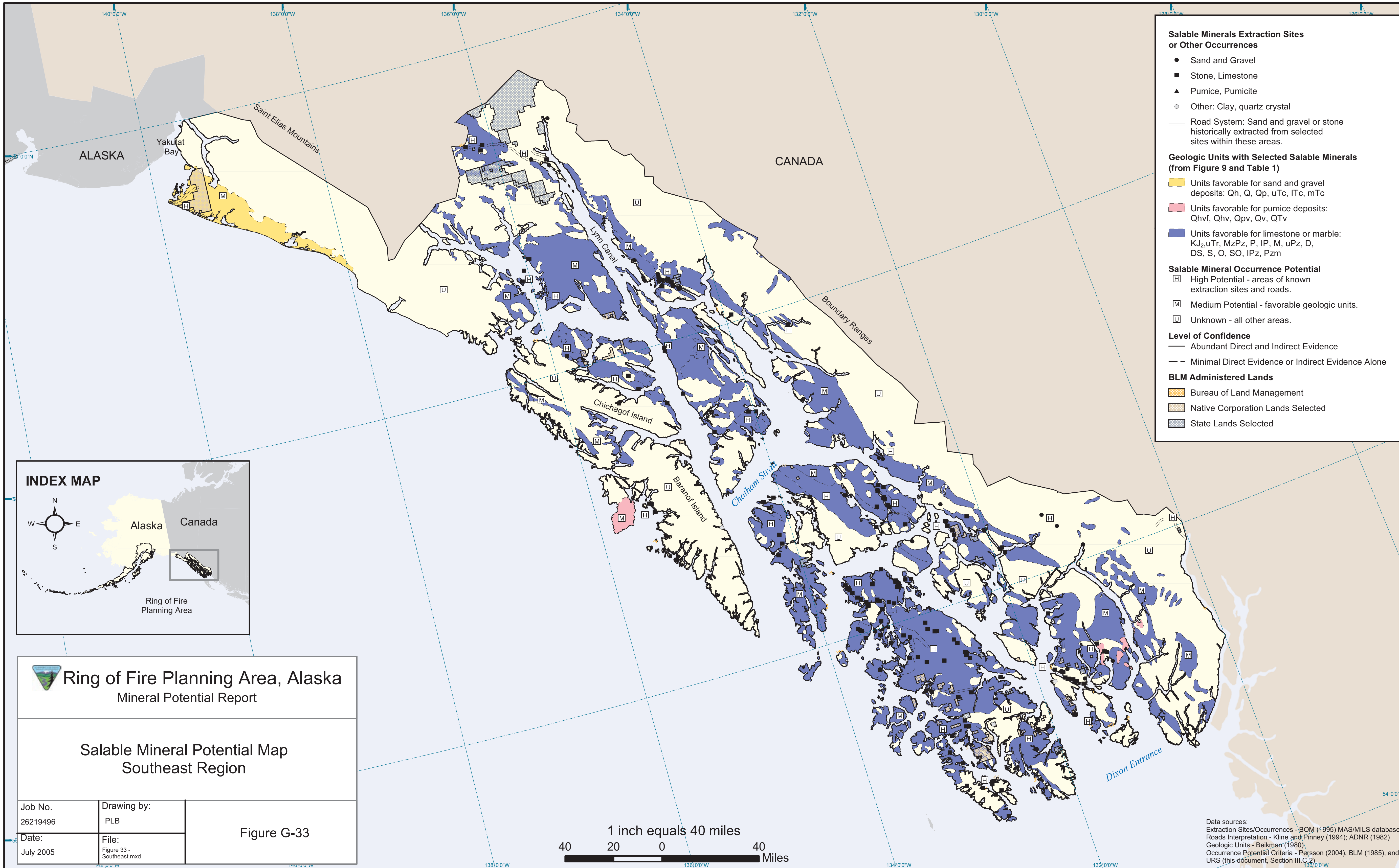
Bureau of Land Management

Figure G-31, Salable Mineral Potential Map, Alaska Peninsula and Kodiak Island



Bureau of Land Management

Figure G-32, Salable Mineral Potential Map, Southcentral Region



Bureau of Land Management

Figure G-33, Salable Mineral Potential Map, Southeast Region

Attachment A

Reasonable Foreseeable Development Scenario For Oil and Natural Gas Resources in the Ring of Fire Planning Area, Alaska

July 2006

REASONABLE FORSEEABLE DEVELOPMENT SCENARIO FOR OIL AND NATURAL GAS RESOURCES IN THE RING OF FIRE PLANNING AREA, ALASKA

Prepared by

U. S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

ALASKA STATE OFFICE

DIVISION OF ENERGY AND SOLID MINERALS

JULY 2006

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ACRONYMS AND ABBREVIATIONS

2D	two dimensional
3D	three dimensional
ADNR	Alaska Department of Natural Resources
AEO	average estimated output
API	American Petroleum Institute
bbl	barrel
bbls	barrels
BBO	billion barrels of oil
Bcf	billion cubic feet
BCFG	billion cubic feet of gas
BLM	Bureau of Land Management
bpd	barrels per day
CBNG	Coalbed natural gas
CFR	Code of Federal Regulations
DOG	Division of Oil and Gas
DST	drill stem test
°F	degrees Fahrenheit
FEIS	Final Environmental Impact Statement
ft	feet
GIP	gas in place
KNWR	Kenai National Wildlife Refuge
LNG	liquid natural gas
mcf	thousand of cubic feet
MMBO	million barrels of oil
MWD	measurement while drilling
NEPA	National Environmental Policy Act
NIA	Notice of Intent to Abandon
P&A	plugging and abandoning
PRMP	Proposed Resource Management Plan
psi	pounds per square inch
RFD	Reasonably Foreseeable Development
SMA	Surface Mangement Agency
sq mi	square mile
Tcf	trillion cubic feet
TCFT	trillion cubic feet of gas
URS	URS Corporation
U.S.	United States
USDOI	U.S. Department of Interior
USEPA	United States Environmetnal Protection Agency
USGS	U.S. Geological Survey
WW II	World War II

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EXECUTIVE SUMMARY

This Reasonably Foreseeable Development (RFD) scenario represents the most likely projection of oil and gas exploration, development, production, and abandonment activity in the Ring of Fire planning area through 2020. Estimating how much oil and gas activity will occur in the Ring of Fire planning area during the next 15 years is difficult at best. Timing and location of future commercial-sized discoveries cannot be predicted until exploration of those reserves occurs. This scenario projects development on the assumption that all areas are open to development under standard lease terms and conditions except those areas closed by statute or for discretionary reasons. Separate estimates are given for seismic activity, drilling, and production activities during the next 15 years. Coalbed natural gas (CBNG) is considered separately from conventional oil and gas.

The Ring of Fire planning area encompasses approximately 1.3 million acres of Bureau of Land Management (BLM)-administered lands in south central Alaska. These lands extend roughly in a 2,500 mile arc from the Aleutian Islands in the southwest, through the Alaska Peninsula and Cook Inlet/Chugach Mountains region, to the panhandle of the southeast Alaska. Three petroleum basins fall entirely or partially within the planning area. These basins, the Bristol Bay Basin (referenced in this report as the Alaska Peninsula Province), Cook Inlet Basin, and the Gulf of Alaska Onshore Tertiary Basin are considered prospectively valuable for oil and gas resources. The analysis of hydrocarbon resource occurrence potential is focused in and around these basin boundaries.

The United States (U.S.) Geological Survey (USGS) has identified six conventional oil and gas plays in the Ring of Fire planning area. These play areas serve as the focus for the projection of oil and gas development within the planning area. The USGS has not conducted a CBNG play analysis within the planning area to date.

Based on the Alaska Department of Natural Resources (ADNR) Five Year Oil and Gas Leasing Program Schedule, the Division of Oil and Gas (DOG) will conduct one lease sale a year from 2004 to 2008 within the Cook Inlet Basin area. In addition, DOG will also hold lease sales once a year within the Alaska Peninsula from 2005 to 2008. Should DOG continue this leasing trend, an additional 24 lease sales (1 per year from 2009 through 2020, 12 in each area) would occur within both the Cook Inlet region and the Alaska Peninsula.

From 1991 through 2003, 11 oil exploration wells were drilled in the Cook Inlet Basin. Given the life of the plan (15 years), roughly 15 oil exploration wells would likely be drilled in the Ring of Fire planning area throughout this timeframe. Between 1973 and 2003, 18 gas exploration wells have been drilled in the Ring of Fire planning area, averaging one gas exploration well drilled per year. However, 17 of these wells were drilled in the last 10 years, indicating a substantial increase in gas exploration in recent years. Should this rate of exploration continue, it is assumed that in the next 15 years, 26 gas exploration wells would be drilled throughout the Cook Inlet Basin.

From 1973 to 2003, 53 oil development wells were drilled in the Cook Inlet Basin. Eleven of these wells, roughly one per year, were drilled in the last ten years. Assuming this one-well-per year trend continues, another 15 oil production wells would be drilled in the next 15 years.

In the same 30-year timeframe, 78 gas development wells, or roughly three wells per year, were drilled in the Cook Inlet Basin. Forty-one of these wells, roughly four per year, were drilled in the last 10 years. Assuming this four-wells-per-year trend continues, another 60 gas production wells would be drilled in the next 15 years.

CBNG development in the Cook Inlet Basin would likely occur in the Matanuska-Susitna Valley and in the southern Kenai Peninsula near Homer. Although these locations are part of the mature Cook Inlet oil and gas basin, we consider this a frontier area regarding CBNG exploration due to limited exploration efforts to date in the Matanuska-Susitna Valley. Under this RFD scenario for CBNG production through 2020, recoverable reserves are assumed to be 1.4 trillion cubic feet (Tcf). The CBNG field would be similar in extent to the established Pioneer Unit, approximately 50,000 acres. To maximize recovery and minimize waste, a 100-acre well spacing pattern would be employed and 500 exploration wells (250 pads or two wells per pad) would ultimately be drilled. Ten percent of these wells would be abandoned as dry holes. Projected acreage disturbance due to CBNG exploration and development under this scenario would total about 1,464 acres.

Total surface disturbance of projected short-term oil and gas exploration and development, including CBNG, is estimated at 2,558 acres.

1.0 INTRODUCTION

Presented in this document is a RFD scenario prepared by BLM, Alaska State Office, in support of the Ring of Fire Proposed Resource Management Plan (PRMP)/ Final Environmental Impact Statement (FEIS). A "Reasonably Foreseeable Development scenario" for oil and gas is a long-term projection (scenario) of oil and gas exploration, development, production, and reclamation activity. The RFD covers oil and gas activity in a defined area for a specified period of time. The RFD projects a baseline scenario of activity assuming all potentially productive areas can be open under standard lease terms and conditions, except those areas designated as closed to leasing by law, regulation or executive order. The baseline RFD scenario provides the mechanism to analyze the effects discretionary management decisions have on oil and gas activity.

The RFD also provides basic information that is analyzed in the National Environmental Policy Act (NEPA) document under various alternatives (U.S. Department of the Interior [USDOI]-BLM IM No. 2004-089).

Impacts caused by oil and gas development, and impacts to oil and gas development cannot be accurately assessed without estimating future oil and gas activities. Estimates of these future activities need to address current crude oil and natural gas prices, anticipated crude oil and natural gas prices, oil and gas occurrence potential, new oil and gas plays, as well as renewed interest in old plays, leasing, seismic survey results, drilling, and production.

2.0 DESCRIPTION OF GEOLOGY

The Ring of Fire planning area encompasses approximately 1.3 million acres of BLM-administered lands in south central Alaska. These lands extend roughly in a 2,500-mile arc from the Aleutian Islands in the southwest, through the Alaska Peninsula and Cook Inlet/Chugach Mountains region, to the panhandle of the southeast Alaska (Figure 1).

Three petroleum basins fall entirely or partially within the Ring of Fire planning area (Ehm 1983) (Figures 1-3). These basins, the Cook Inlet Basin, the Gulf of Alaska Onshore Basin and the Bristol Bay Basin (referenced in this report as the Alaska Peninsula Province) are considered prospectively valuable for oil and gas resources. The analysis of hydrocarbon-resource occurrence and development potential within the Ring of Fire planning area is focused in and around these basin boundaries. For a more comprehensive discussion of the geology and mineral resources of the Ring of Fire planning area, see URS Corporation (URS) (2005).

2.1 COOK INLET BASIN

The Cook Inlet Basin is a northeast-trending forearc basin 200 miles long and 60 miles wide. It covers some 12,000 square miles (sq mi) and is filled with more than 25,000 feet (ft) of Tertiary non-marine sediments. Rocks in the basin area range in age from Pennsylvanian to Recent.

2.1.1 USGS Oil and Gas Play Overview

The following excerpt is from a USGS oil and gas play description for the Cook Inlet Basin (Magoon et al. 1996).

The Cook Inlet Basin produces oil and gas from Tertiary sandstone reservoir rocks that were deposited in a forearc basin. Biogenic gas is produced from the late Tertiary sandstone reservoir rocks, whereas oil with associated gas is produced from the early Tertiary conglomeratic sandstone and sandstone reservoir rocks. Minor amounts of oil have been recovered from late Mesozoic sandstone unconformably underlying the Tertiary rocks. The source rock is the Middle Jurassic Chuitna Formation in upper Cook Inlet, whereas the Upper Triassic and Middle Jurassic are the source rocks for the oil shows in lower Cook Inlet. In upper Cook Inlet, oil generation began as early as the Eocene and peaked in the Pliocene. Until recently, discovered resources were about 1.2 BBO, but with the Sunfish discovery and the McArthur River extension, discovered resources may exceed this amount in upper Cook Inlet.

2.2 ALASKA PENINSULA PROVINCE

The Alaska Peninsula Province forms the eastern boundary of the Bristol Bay Basin. The Peninsula is located west and southwest of Cook Inlet. It extends in a curving 400 mile arc from the vicinity of Lake Illiamna in the northeast to Isanotski Strait at its tip in the southwest. The Peninsula decreases in width from about 100 miles across its base to about 3 miles at its tip. The Alaska Peninsula is primarily a province of Mesozoic and Cenozoic sediments heavily influenced by volcanic and plutonic activity.

2.2.1 USGS Oil and Gas Play Overview

The following excerpt is from USGS oil and gas play descriptions for the Alaska Peninsula (Magoon et al. 1996).

Alaska Peninsula Mesozoic Play (Hypothetical): This is a hypothetical structural play for Mesozoic accumulations under large anticlines along the Alaska Peninsula. The play area includes the outcrop belt of Mesozoic rocks and part of the southwestern Bristol Bay lowlands where Mesozoic rocks are thought to be preserved. The play area is about 440 miles long and 30 to 50 miles wide, extending from lower Cook Inlet on the northeast to the last outcrops of sedimentary rocks in the Cold Bay area on the southwest. The southeast boundary is the national offshore 3-mile territorial limit along the Gulf of Alaska and the northwest boundary is the Bruin Bay Fault and its southwestern projection into the Port Heiden area.

Alaska Peninsula Tertiary Play (hypothetical): This is a hypothetical play for petroleum accumulations in Tertiary shallow marine and nonmarine sandstone in broad open folds underlying alluvium of the Bristol Bay lowlands on the northwestern side of the peninsula. The play area extends from about Becharof Lake, part way down the peninsula, to a narrow strip of coastline opposite Cold Bay, a distance of about 300 miles. The northwest boundary is the national 3-mile offshore territorial limit, and it adjoins the offshore North Aleutian Basin. The average width is about 25 miles.

2.3 GULF OF ALASKA ONSHORE BASIN

The Gulf of Alaska Onshore Tertiary Basin is a lowland and foothills belt 300 miles long and up to 40 miles wide. The onshore province lies seaward of the Chugach-Saint Elias and Fairweather Faults and is bordered by the Ragged Mountain Fault in the west and by Cross Sound in the east.

This distinct physiographic and geologic province is underlain by a thick sequence (over 9 miles) of continental and marine sedimentary rocks that decrease in age seaward (Paleocene through Holocene) (Bayer et al. 1977; Bruns and Plafker 1982). The Tertiary sequence is broadly divisible into two stratigraphic units: 1) a thick lower unit of intensely deformed, well indurated rocks of Paleocene to Eocene age; 2) a less deformed and indurated upper unit of Oligocene to Pliocene age that contains most of the known indications of oil and gas in the province.

Gulf of Alaska Tertiary province can be divided into three major subdivisions that correspond to major tectonic and depositional changes since early Tertiary time (Plafker 1971; Bayer et al. 1977; Bruns and Plafker 1982; Bruns 1988). The major subdivisions are:

1) a lower Tertiary sequence (Paleocene through lower Oligocene) of hard, dense, and intensely deformed and faulted rocks. It is composed of the Orca Group, Stillwater, lower Tokun, and Kulthieth Formations. The Orca Group is a flysch-like sequence of turbidites and interbedded pillow basalts that likely represent deep-sea fan deposits. Continental to shallow marine coal-bearing clastic rocks of the Stillwater, lower Tokun, and Kulthieth Formations, overlie the Orca Group in outcrop, the sequence totals about 22,000 ft in the Katalla district, but appears to thin toward Yakutat Bay. Sandstones in the Kulthieth Formation are potential reservoir rocks for oil and gas (Bird and Magoon, 1988);

2) a middle Tertiary sequence (middle Oligocene through lower Miocene) of richly organic mudstone and siltstone. It unconformably overlies the lower Tertiary strata. This sequence consists of up to 6,000 ft of the Poul Creek Formation including the Katalla Formation (Miller 1975), and up to 2,500 ft of Cenotaph Volcanics and the Topsy Formation. In the central part of the Gulf of Alaska Tertiary province, the middle Tertiary sequence contains many petroliferous beds as well as seeps of oil and gas. Thickness of the middle Tertiary sequence in outcrop varies abruptly within short distances. It ranges from a few hundred ft in the Malaspina district to about 9,000 ft in the Katalla district. Marine shales of the Poul Creek Formation are potential source rocks for oil and gas (Bird and Magoon 1988); and

3) a Miocene through Holocene sequence of about 3,700 ft of nonglacial clastic sediments (conglomerate and sandstone) of the Redwood Formation and up to 18,000 ft of interbedded siltstone, mudstone, sandstone, and conglomeritic sandy mudstone of the Yakataga Formations. These strata are interpreted as marine diamictite with abundant glacial detritus deposited close to tide water by ice rafting. Sandstones in the Yakataga Formation are potential reservoir rocks for oil and gas (Bird and Magoon 1988).

2.3.1 USGS Oil and Gas Play Overview

The following excerpt is from a USGS oil and gas play description for the Gulf of Alaska Tertiary Basin (Magoon et al. 1996).

Yakutat Foreland/Lituya Play (hypothetical): This hypothetical play includes hypothetical accumulations of petroleum, mainly oil and associated gas, in relatively undeformed strata of Cenozoic age. The play lies between Icy Bay and Cape Fairweather, seaward of the Fairweather and Boundary Faults. The play includes the areas beneath the ice of the Malaspina Glacier and the waters of Yakutat Bay, beneath the Yakutat Foreland, the coastal plain between Yakutat Bay and Cape Fairweather, and the Lituya Bay area. Since much of the play is covered by ice, water, or Quaternary alluvium, little is directly known of subsurface structure. The part that lies north or northeast of the onshore continuation of the Dangerous River zone is underlain by rocks of the Yakutat Group; these rocks have been sampled in coreholes east of Yakutat Bay.

Tertiary strata dip steeply away from, and thicken seaward along and south of, the Dangerous River zone. Seaward of and along the Dangerous River zone continuation, thick sedimentary rocks are present and are inferred to include equivalents of the Paleogene Stillwater, Kulthieth, and Tokun Formations, the Oligocene and Miocene Poul Creek Formation, and the Miocene and younger Yakataga Formation. Onshore, Paleogene and Poul Creek Formation strata thin to the east; these strata are as much as 13,000 ft and 6,000 ft thick, respectively, west of Icy Bay but are not known to be exposed in the Lituya Bay area. The Yakataga Formation is as thick as 13,000 ft thick at Icy Bay and also thins to the east. However, just offshore, Paleogene rocks are up to 13,000 ft thick, and Yakataga Formation equivalents are up to 17,000 ft thick. Thus, thick sequences of Paleogene rocks are likely present beneath Malaspina Glacier and Yakutat Bay, and they have been sampled in wells near the shoreline in both Icy Bay and Yakutat Bay, and near the town of Yakutat.

3.0 PAST AND PRESENT OIL AND GAS EXPLORATION ACTIVITY

Similar to the exploration and development efforts in the Cook Inlet Basin, exploration in the Alaska Peninsula and Gulf of Alaska onshore basins has historically focused on structural plays in the search for oil with no attempt to evaluate stratigraphic potential. It should also be noted that during these past exploration efforts, a well having good gas “shows” (evidence for the presence of hydrocarbons) or flowing small to moderate amounts of natural gas was considered insignificant because there was no market for the natural gas.

3.1 COOK INLET BASIN

The first attempt at commercial oil exploration in the Cook Inlet Basin took place on the Iniskin Peninsula in western Cook Inlet where six exploration wells were drilled between 1900 and 1906. Although these proved not to hold commercial quantities of oil and gas, exploration continued throughout the basin for the next 50 years. Commercial oil was finally found in Alaska in 1957 with the Swanson River discovery well drilled by Atlantic Richfield Oil Company in the Kenai National Moose Range, now referred to as the Kenai National Wildlife Refuge (KNWR). The well flowed at a rate of about 900 barrels a day from a depth of 11,000 ft. The first major gas discovery occurred in 1959 by Union Oil Company of California and Ohio Oil Company in the Kenai gas field. In 1962, Pan American Petroleum Corporation discovered the first offshore oil in Cook Inlet. This led to extensive exploration throughout the Cook Inlet region in the 1960s and 1970s.

Eighteen gas fields and eight oil fields have been discovered in the Cook Inlet Basin to date. The McArthur River field, discovered in 1965 and located offshore, is the largest Cook Inlet oil field. The last oil field discovery was the Sunfish/Tyonek Deep in 1991, also located offshore. The Kenai gas field was the first and continues to be the largest commercial gas field in the basin. The most recent gas discovery in the basin was the Happy Valley field in 2003.

Approximately 270 exploration wells have been drilled in the Cook Inlet Basin to date. Of these exploration wells, 24 have been drilled for gas. Natural gas in the basin is found in the Sterling, Beluga, and Tyonek Formations and comes primarily from Tertiary coals (biogenic gas). Oil is found in the Hemlock, Lower Tyonek, and West Forelands Formations. The sources of oil for the Cook Inlet Basin are marine shales of the middle Jurassic Tuxedni Formation.

Coalbed Natural Gas: Demand for natural gas has led to a dramatic increase in CBNG drilling and production since 1996, primarily in Rocky Mountain Basins of the lower 48 states. High natural gas prices are making CBNG economically viable where it previously may not have been. Unlike coventional natural gas wells, CBNG wells produce at low gas rates (typically maxing out around 300 thousand cubic ft (mcf) per day, and can have large inital costs.

Recent oil and gas exploration in the State has included a focus on CBNG exploration, most notably in the Matanuska-Susitna Valley located in the northeastern Cook Inlet Basin. CBNG is a form of natural gas that occurs in large quantities in coal seams. Unlike conventional oil and gas formation, coal is both the source rock and reservoir rock for a CBNG well. Methane is the lightest component of the hydrocarbon chain, meaning that a methane molecule has the highest ratio of hydrogen atoms to carbon atoms. The gas is typically contained within the internal surfaces of the coal and is held in place by hydrostatic pressure created by the presence of water. During production, this water is pumped to the ground surface, which lowers the pressure in the coalbed reservoir and stimulates the release of gas from the coal. The gas itself, which is almost entirely methane, eventually flows through fractures in the coal to the well bore and is captured for use. It may take a while to know whether a well will produce gas, and even longer to know whether it will produce commercial quantities. Gas flow does not peak for a considerable time after initial production.

Until the 1980s, coal seams generally were not considered to be reservoir targets, even though producers often drilled through coal seams to reach deeper hydrocarbon-bearing sandstone and limestone reservoirs. During the second half of the 1990s, CBNG production increased dramatically nationwide to meet ever-growing energy demands.

In the Cook Inlet Basin, coal is the source of up to 7.7 Tcf of the basin's 8.3 Tcf of "conventional" gas (Thomas et al. 2004). The economic viability and timing of any contribution from this resource remains highly uncertain because of high development costs, the lack of sufficient data to predict gas productivity, the amount of water that must be handled and land access issues.

In 1994, the state drilled a CBNG test well near existing roads and pipelines in Wasilla, Alaska (well AK-94 CBNG -1) to a total depth of 1,245 ft in the Tyonek Formation. Eighteen seams of bituminous coal were encountered, the thickest at 6.5 ft, with a net coal thickness of 41 ft (Smith 1995). Thirteen of these seams were sampled for gas content using 38 gas desorption canisters, however, the well was not flow tested due to budget constraints. Smith (1995) reported the following data based on the results of the test well: 1) the CBNG gas has both biogenic and thermogenic sources; 2) the gas content, 98 percent methane, increases with depth; 3) coal moisture is low (9.02 percent at 521 ft and 4.82 percent at 1,236 ft); and 4) upon visual analysis, coal cleat and fracture density is widely spaced. Encouraged by the results of this well, the Alaska Division of Geological and Geophysical Surveys has embarked on a multi-year study to determine whether CBNG could serve as a local energy source in rural Alaska.

Industry exploration efforts in the Matanuska-Susitna Valley began in the late 1990s and included core samples and the drilling of several pilot wells in bituminous coal seams of Tertiary age. In June of 2003, Evergreen Resources began pilot production in the Pioneer Unit (Figure 2) to test the commercial viability of CBNG near Wasilla. The goal of a pilot test is to dewater a portion of the reservoir and record the resulting production profile as quickly as possible. The results provide the basis for determining whether to develop the field and at what well-spacing pattern (Allen 2001). The testing program involved two four-well pilots consisting of three wells forming an equilateral triangle (600 to 700 ft on a side) with a fourth well in the center. The wells reportedly contain up to 160 ft of coal within an approximate cross section of 600 to 1,000 ft (Thomas et al. 2004). Within six months, five of the CBNG wells produced over 2 mcf of gas and about 2.6 million gallons (62,000 barrels [bbls]) of water. The four remaining wells yielded a combined daily production rate of 10,355 cubic ft of gas and 13,356 gallons (318 bbls) of water during the month of December. Produced gas from the wells was vented, and produced water was re-injected into two nearby wells.

In November 2003, Evergreen announced that “initial production results indicate that the wells in the first two pilot projects are probably not capable of commercial production” (Petroleum News 2003). Evergreen is now drilling five stratigraphic core holes north of the Castle Mountain Fault where coal seams are at shallower depths. The coring program will recover coal core samples to determine methane desorption potential, total aggregate thickness of the coal seams, and other data to help estimate future production (Petroleum News 2003).

3.2 ALASKA PENINSULA PROVINCE

Twenty-eight oil wells have been drilled on the Alaska Peninsula to date. Nine shallow wells were drilled on two different oil seeps prior to 1926 and another 19 deeper wells were drilled between 1940 and 1985. Oil or gas shows were observed in nine of the deeper wells, but commercial quantities of hydrocarbons have not yet been found. The following brief history identifies the Alaska Peninsula as an area that generates continuing, albeit intermittent, interest in the search for oil and gas.

The vast coal resources and surface oil seeps on the Alaska Peninsula have attracted exploration interest since the mid-1800s (Table 1). Based on the presence of oil and gas seeps in the vicinity of Puale Bay, then known as Cold Bay, several oil exploration wells were drilled in the early 1900s.

In 1910, the federal government withdrew from entry all oil lands in Alaska (Martin 1921). The Mineral Leasing Act of 1920 renewed interest in the search for oil on the Alaska Peninsula. Oil claims were staked in the vicinity of Puale Bay in the early 1920s (Brooks 1922). Associated Oil Company and Standard Oil of California drilled wells in the early to mid-1920s. Standard Oil drilled two shallow wells and one deep well (about 5,400 ft) without striking commercial quantities of oil (Brooks 1925; Moffitt 1927). Both companies abandoned drilling on the Peninsula by early 1926 (Smith 1929).

By the mid-1930s, the Puale Bay area was once again the scrutiny of oil exploration. Geologists from Standard Oil Company of California, the Tide Water Associated Oil Company and Union Oil Company of California, drilled wells in the Bear Creek Unit area near Jute Bay in 1939. The venture reported no showings of commercial quantities of oil (Smith 1939).

Interest in the oil potential of the Alaska Peninsula lay dormant throughout the 1940s and into the mid-1950s. From 1957 through 1959, Humble Oil and Refining Company drilled the Bear Creek Unit No. 1 to a depth of 14,375 ft and encountered no commercial quantities of oil (Blasko 1976). Several wells have been drilled on the Alaska Peninsula in recent years, the last drilled and abandoned in 1985.

Coalbed Natural Gas: The Alaska Peninsula Province contains coals of Cretaceous and Tertiary age separated by a regional unconformity (Smith 1995). The Cretaceous coals, bituminous in rank, occur in the Chignik Formation and have been penetrated by at least three oil and gas exploration wells (Smith 1995). All had excellent mudlog gas shows. The Tertiary coals range from lignite to bituminous in rank and occur in the Tolstoi, Stepovak, and Bear Lake Formations. These coal seams have been penetrated by five oil and gas exploration wells and reportedly contain minor to good gas shows (Smith 1995). The Tertiary coals extend along the north side of the Alaska Peninsula for over 250 miles.

3.3 GULF OF ALASKA ONSHORE BASIN

The petroleum potential of the onshore Gulf of Alaska Tertiary Basin was first recognized through the discovery of oil and gas seeps east of Katalla in 1896. From 1901 to 1933, 44 shallow wells were drilled in the Katalla area, 28 wells at the Katalla field, and 16 wells at nearby locations. Most wells had oil shows, some had gas shows, and 18 produced oil commercially (about 154,000 bbls) from fracture porosity in sandstone and siltstone of the Poul Creek Formation at depths ranging from 360 to 1,750 ft.

The Katalla field became the only productive area in the Gulf of Alaska Tertiary Basin. Operation of a small refinery at the field began in 1911 but production abruptly ended when the refinery burned down in 1933 (Miller et al. 1959; Blasko 1976; Bruns and Plafker 1982). Although active natural gas seeps were known in this area, there are no records of gas production from this period.

East of Katalla in the coastal area of Yakataga, oil and gas seeps are found on numerous creeks draining southward toward the ocean. The first test well in this area, drilled between 1926 and 1927, had shows of oil and gas. After World War II (WW II), leasing activity on previously withdrawn lands resumed, and in 1951, hundreds of individuals applied for leases covering nearly one million acres in the coastal areas between the Copper River and Cape Fairweather (Miller et al. 1959). Exploration for onshore oil and gas deposits within the basin continued from 1954 to 1963 when an additional 25 wells and five core holes were drilled. Although all were abandoned, records indicate shows of oil and/or gas in nine of the wells (Plafker 1971). No commercial hydrocarbon field has been discovered in the basin to date.

4.0 PAST AND PRESENT OIL AND GAS DEVELOPMENT ACTIVITY

The Cook Inlet Basin is currently the only commercially producing oil and gas region within the Ring of Fire planning area and is the focus of past and present oil and gas development.

4.1 COOK INLET BASIN

Before Prudhoe Bay and the North Slope made the State famous for oil and gas, Alaska's first commercial oil production came from discoveries in Cook Inlet. The Swanson River discovery is often credited as one of the key factors in Alaska becoming the 49th state by showing that Alaska could support itself through resource development revenues. In 1959, two years after the discovery of oil in the Swanson River field, the State established a competitive leasing program by issuing 77,000 lease acres in Cook Inlet Basin and receiving $4 million in bonus bids. Over 5.6 million acres of state land have been leased in 40 state oil and gas lease sales in the Cook Inlet region since 1959. Prior to statehood in 1959, the federal government conducted non-competitive lease sales. About 67,000 acres of the non-competitive federal leases remain active in the Cook Inlet Basin. One competitive federal lease has been issued to date, a 400-acre parcel receiving over $4.5 million in bonus bids.

The first major gas discovery was made in the Kenai field by the Union Oil Company of California and Ohio Oil Company in 1959. Gas production in Cook Inlet began the following year when the Anchorage Natural Gas Corporation signed a 20-year contract for Kenai field gas. By 1983, annual natural gas production had reached 196.4 billion cubic ft (Bcf). Efforts to explore specifically for natural gas in the Cook Inlet Basin did not take place until the late 1990s.

In 1960, following further development of the Swanson River and Soldotna Creek Units, annual production rose to 600,000 bbls. Production peaked at 83 million bbls in 1970. In 1968, Unocal began producing ammonia-urea at a plant in Nikiski, 70 miles southwest of Anchorage, to take advantage of the abundant, inexpensive natural gas. This plant, acquired by Agrium, Inc. in 2000, currently faces a decline in production due to inadequate affordable supplies of natural gas in south central Alaska.

Tesoro Alaska opened the state's first oil refinery in 1969 near Kenai. Based on market demand, throughput rates in recent years have been approximately 50,000 barrels per day (bpd) or 18 million barrels per year. A 70-mile, 37,000 bpd pipeline links the refinery to an Anchorage terminal. The refinery draws feedstock from Cook Inlet and other sources to produce jet fuel, diesel fuel and heating oil, gasoline, liquefied petroleum gas, heavy oils and bunkers, and liquid asphalt. All of the refinery output is consumed within Alaska.

As additional oil and gas fields were discovered in the basin, local demand for the natural gas increased through growing residential and commercial demand (e.g., space heating and electric power generation) in Anchorage and Kenai. In 1969, Phillips and Marathon began operating a liquid natural gas (LNG) plant, located at Nikiski. The plant liquefies one million tons of LNG annually and is the only natural gas liquefaction plant in the U.S. In recent years, LNG exports to Japan accounted for about one third of total production. Cook Inlet natural gas production has remained relatively stable at an average of 213 Bcf per year from 1997 to 2001.

5.0 OIL AND GAS OCCURRENCE POTENTIAL

A projection of future oil and gas activity must first consider where oil and gas resources might occur. Several geologic elements are necessary for oil and gas to accumulate in sufficient quantities. These elements include an organic-rich source rock to generate oil or gas, the combined effects of heat and time, a porous and permeable reservoir rock to store the petroleum in, and some sort of trap to prevent the oil and gas from migrating to the surface. Traps generally exist in predictable places, such as at the tops of anticlines, next to faults, in the updip pinchouts of sandstone beds, or beneath unconformities. Map 4 was drawn to show the occurrence potential for oil and gas throughout the Ring of Fire planning area, and is not meant to imply these resources can be developed economically.

The mineral occurrence potential assignment conforms to the rating system outlined in BLM Handbook H-1624-1, Planning for Fluid Mineral Resources. This system is designed to remain dynamic. As new data is received it can be used to change the rating. The ratings used have four levels: high, medium, low, and no known. The following definitions were used to classify the oil and gas occurrence potential:

HIGH: Inclusion in an oil and gas play as defined by the 1995 USGS National Assessment. In the absence of a play designated by the USGS, a high potential classification was assigned based on the demonstrated existence of: 1) source rock; 2) thermal maturation; 3) reservoir strata possessing permeability and/or porosity; and 4) traps.

MEDIUM: Geophysical or geological indicate the following may be present: 1) source rock; 2) thermal maturation; 3) reservoir strata possessing permeability and/or porosity; and 4) traps. Geological indication is defined by geological inference based on indirect evidence.

LOW: Specific indications that one or more of the following may not be present: 1) source rock; 2) thermal maturation; 3) reservoir strata possessing permeability and/or porosity; and 4) traps.

NO KNOWN: There is a demonstrated absence of a petroleum source, reservoir quality strata, or trapping mechanisms. Demonstrated absence is defined by physical evidence or documentation in the geological literature.

The rationale for determining occurrence potential within Ring of Fire planning area is based primarily on three sources: 1) geology; 2) oil and gas basins map of Alaska; and 3) conventional oil and gas play areas described by the USGS 1995 National Oil and Gas Assessment. The play descriptions include discussions on reservoir rocks, source rocks, exploration status, and resource potential.

Beikman (1980) constructed a generalized geology map of Alaska. This information was used to identify areas within Ring of Fire planning area consisting primarily of igneous and metamorphic rocks. These areas were eliminated from further consideration as prospective oil and gas resources and assigned no known potential. Ehm (1983) delineated three petroleum basins that fall either partially or entirely within Ring of Fire planning area. These basins are generally considered prospective for oil and gas resources and serve as the focus for further analysis using available exploration and drilling data and USGS play descriptions.

The USGS has identified six conventional oil and gas plays in Ring of Fire planning area. A play is a set of discovered or undiscovered oil and gas accumulations or prospects that exhibit nearly identical geological characteristics. A play is defined, therefore, by the geological properties, such as trapping style, type of reservoir, nature of the seal, that are responsible for the accumulations or prospects.
Two principal categories of conventional plays were assessed by in the 1995 USGS National Assessment – confirmed plays and hypothetical plays. A play was considered confirmed if one or more accumulations of the minimum size (one million barrels of oil [MMBO] or six billion cubic ft of gas [BCFG]) had been discovered in the play. Hypothetical plays were identified and defined based on geologic information but for which no accumulations of the minimum size had, as yet, been discovered.

Using these definitions, two plays in the Cook Inlet Basin are confirmed and the remaining four plays are hypothetical. As such, hypothetical plays characteristically carry a much broader degree of uncertainty than do confirmed plays.

5.1 COOK INLET BASIN

The following USGS conventional oil and gas play descriptions for the Cook Inlet Basin are from Magoon et al. (1996).

The Cook Inlet area has been divided into three plays. They are the Beluga-Sterling Gas Play, the Hemlock-Tyonek Oil Play, and the Cook Inlet Late Mesozoic Oil Play, with the latter being a hypothetical play. The Beluga-Sterling Gas Play is a confirmed play for additional gas accumulations, covering 12,318 sq mi of the Cook Inlet Basin and including 18 gas fields containing discovered reserves of 6.14 trillion cubic feet of gas (TCFG). The three largest fields are Kenai (2.52 TCFG), North Cook Inlet (1.44 TCFG), and Beluga (0.86 TCFG). Many of the gas fields are undeveloped because they are too small and too expensive to produce.

Most of the gas is produced from the Sterling Formation, followed by the Beluga Formation and Tyonek Formation. The reservoir rocks in these formations are siliclastic sandstones of late Tertiary age whose average thickness ranges from 24 to 600 ft. The porosity of these reservoirs ranges from 18 to 35 percent and permeability ranges from 3.5 to 4,400 mD. The seals for these accumulations are siltstones associated with these reservoirs. The traps, which can be more than one per field, are mostly structural, but include some combined structural and stratigraphic traps. Structural traps include anticlines and faulted anticlines.

The natural-gas field sizes range from 6 BCFG to 2.52 TCFG. The gas is believed to be biogenic. The stratigraphic section is thermally immature and unable to generate methane. Biogenic gas generated locally would have migrated to adjacent structures or other types of traps.

The Hemlock-Tyonek Oil Play confirms oil accumulations covering 7,335 sq mi of the Cook Inlet Basin and including eight oil fields, two of which were just discovered. So little information is available for the two newly discovered fields that they have been excluded from this discussion. The three largest producing fields are McArthur River (590 MMBO), Swanson River (230 MMBO), and Middle Ground Shoal (182 MMBO).

Eighty percent of the oil is in the Oligocene Hemlock Conglomerate, a conglomeratic sandstone, with the remainder coming from the Oligocene and Miocene Tyonek Formation, a siliciclastic sandstone, and the Eocene West Foreland Formation, a volcaniclastic sandstone. The reservoir thickness ranges from 100 to 1,320 ft. Reservoir porosity ranges from 11 to 20.5 percent, and permeability from 10 to 4,960 mD. The seals for these accumulations are siltstones associated with these reservoirs. The traps are all structural.

The oil has an American Petroleum Institute (API) gravity that ranges from 31° to 42° and a low sulfur content (<0.2 percent). It originated from the Middle Jurassic Chuitna Formation between the Swanson River and Middle Ground Shoal fields. Based on burial history of the source rock, the oil was generated as early as the Eocene and continued into the Pliocene.

The Cook Inlet Late Mesozoic Oil Play covers 8,518 sq mi of accumulations in structural traps throughout the Cook Inlet Basin. The section unconformably underlies the Tertiary sedimentary rocks. Oil has been recovered from the Mesozoic from several wells in the Outer Continental Shelf in lower Cook Inlet and from wells in the Swanson River field area on the Kenai Peninsula.

Potential reservoir rocks are shallow marine and turbidite sandstones within the Upper Cretaceous Matanuska and Kaguyak Formations, Lower Cretaceous calcarenite, and feldspathic sandstones in the Upper Jurassic Naknek Formation. Where these units are penetrated by wells or found in outcrop, they are of poor reservoir rock quality. Seals are siltstones adjacent to these reservoirs and in the unconformably overlying Eocene West Foreland Formation.

The traps are mostly faulted anticlines that are truncated by the overlying Tertiary rocks, which in many cases contain the oil that migrated up through the Mesozoic section. Other possibilities are unconformities and stratigraphic traps, but these would be very difficult to map using such poor-quality seismic data.

As in the Hemlock-Tyonek Oil Play, the oil is expected to have an API gravity that ranges from 31° to 42° and a low sulfur content (<0.2 percent) and to have originated from the Middle Jurassic Chuitna Formation between the Swanson River and Middle Ground Shoal fields. Based on the burial history of the source rock, the oil was generated as early as the Eocene and continued into the Pliocene.

Coalbed Natural Gas: Coal is abundant in portions of the Tertiary rocks of both the Cook Inlet and Susitna Basins and provides a potential source for large quantities of dry gas. The coal rank ranges from lignite in the Sterling Formation to anthracite in the Chickaloon Formation (Montgomery et al. 2003). Bituminous coals are limited to the Wasilla-Houston area of the Susitna Basin along the Castle Mountain Fault. Sub bituminous coals are found along the western margin of the Susitna Basin and in the Beluga and Yentna coal fields.

The Cook Inlet Basin contains coal deposits within the Chickaloon Formation at its northeast corner and in the Tyonek Formation across its entire extent. Uplift during the Holocene brought thick coals of these formations near the surface, making some onshore areas of the basin prospective for CBNG exploration (Smith 1995).

Tyonek coals beds are abundant and continuous, exceeding 40 ft in thickness. Desorption values for sub bituminous Tyonek coals taken from the State's core test (well AK94 CBNG #1) exceed 100 cubic ft per ton (ADNR/DOG 2004). The core test found multiple seams of sub bituminous coal in a shallow reservoir setting. Desorbed gas content generally increased with depth and exceeded 245 cubic ft per ton at a depth of 1,200 ft for one sample tested. Fracture and cleating observed in the coal samples were also favorable for the producibility of gas from the coals.

Coals of the 3,000 foot-thick Chickaloon Formation, mined between 1914 and 1968, are confined to the upper 1,400 ft and range in rank form bituminous to anthracite. Over half of the estimated coal reserves lie at depths between 1,000 to 2,000 ft (Barnes and Payne 1956). Coals lying north of the Castle Mountain Fault in the Susitna Basin reportedly contain high levels of gas based on results from five oil and gas exploration wells and three U. S. Bureau of Mines core holes drilled between 1951 and 1963 (Smith 1995). Small quantities of mostly methane gas are also reported in shallow water wells near the fault (Smith 1995)

The uplifted margins of the both the Cook Inlet and Susitna Basins offer the highest potential for CBNG gas.

5.2 ALASKA PENINSULA PROVINCE

The following USGS conventional oil and gas play descriptions for the Alaska Peninsula are from Magoon et al. (1996).

Alaska Peninsula Mesozoic Play (Hypothetical): Reservoirs: The primary reservoir objective of this play is Upper Triassic reefoid or biostromal limestone that underlies good oil source rocks. At least three wells penetrated the Upper Triassic section, but none found the biostromal limestone facies. Both the Jurassic sandstones, which are either volcaniclastic graywackes or first-cycle arkoses, and the Cretaceous sandstones, which are lithic rich, have poor reservoir potential.

Source rocks: Mesozoic strata consist of thick sections of deep marine to shallow marine to nonmarine mudstone, sandstone, conglomerate, and minor amounts of limestone. Large oil seeps and oil staining in Mesozoic rocks are found in several places on the peninsula, and good type II oil source rocks have been identified in Upper Triassic and possibly Middle Jurassic rocks. Other marine rocks do not seem to have source-rock potential, although nonmarine paludal (marsh) rocks of the Chignik Formation (Upper Cretaceous) in the southwestern part of the peninsula may locally have lipid-rich rocks that may be potential oil source rocks. At Puale Bay, the only place on the peninsula where Triassic rocks are exposed, limited outcrop sampling of a 1,000-ft-thick section of interbedded petroliferous, argillaceous limestone and shale indicated total organic carbon contents of 1.3–2.8 weight percent (Magoon and Anders 1992). These rocks are barely thermally mature (Ro = 0.6 percent) despite their having been buried by at least 14,000 ft of Jurassic rocks plus an unknown thickness of now-eroded Upper Cretaceous rocks. Well penetrations indicate that Triassic rocks at depth are much more mature, with Ro ranging from 1.0 to over 2.0 percent (Molenaar 1996). Some of this variation is due to nearby intrusive rocks, but it does seem that the geothermal gradient at the time of maximum burial (probably in latest Cretaceous or early Tertiary time) was very much lower than the present gradient, which ranges from 1.65 degrees Fahrenheit (°F) to over 2°F per 100 ft based on bottom temperature data from wells (Molenaar 1996).

Exploration status: Of the 18 significant wells drilled on the peninsula, nine were drilled for Mesozoic prospects and most tested large structures without success. The last well was drilled in 1983 and since then, except for an offshore well drilled by Chevron in the Shelikof Strait in 1985, there has been no activity in the area. Drilling depths for the Triassic rocks would be 12,000 to 20,000 ft.

Resource potential: This is a very speculative play and it is difficult to make a meaningful assessment. There are undrilled possibilities such as the Ugashik Anticline, which has three seeps and has only been drilled to shallow depths. The results of previous deep drilling on the nearby Bear Creek Anticline, which also has large oil seeps, and the nearby large Wide Bay Anticline were disappointing. The lack of adequate reservoir rocks seems to be the main drawback to this play.

Alaska Peninsula Tertiary Play (hypothetical): Reservoirs: Sandstone beds 50 ft to over 100 ft thick are generally common throughout the Tertiary section except in the central part of the play area near Port Heiden and the Gulf Port Heiden Unit number 14 well. There, the Oligocene sequence consists of about 6,000 ft of volcanics, pyroclastics, flows, and agglomerates that grade into sandstones and mudstones to the northeast and southwest.

Source rocks: The source rocks are coaly and carbonaceous strata within the Tertiary section and possibly Mesozoic source rocks that may be present under the southwestern half of the play area. Mesozoic strata are not present under the lowlands in the northeastern two-thirds of the Peninsula because of pre-Tertiary erosion. Hence, except for the possibility of Mesozoic oil source rocks, this is most likely a gas play although there is the possibility that lipid-rich paludal rocks in the nonmarine section could be oil prone.

Marginal thermal maturation for hydrocarbons (Ro = 0.6 percent) seems to be at a depth of about 9,000 to 10,000 ft in the play area (Molenaar in press). Geothermal gradients range from 1.65°F to 2.07°F per 100 ft and average about 1.86°F per 100 ft. Because the Tertiary section is now at its greatest depth of burial, any hydrocarbon generation from Tertiary source rocks is likely still progressing.

Exploration status: Between 1959 and 1983, nine tests ranging in depths from 8,000 – 15,000 ft were drilled for Tertiary prospects. Gas shows were encountered and one test had a slight oil show. Although not as indurated as the Mesozoic sandstones, Tertiary sandstones are generally volcanogenic or lithic and of poor reservoir quality. However, good to fair amounts of water were recovered on a few drill-stem tests.

Resource potential: Because the play area is alluvial covered, seismic surveys are necessary to delineate the structure. Nothing has been published on this, but by analogy with adjacent offshore seismic data, it seems that the structures are broad and gentle. The abundance of coal in the section and the low thermal maturity suggests the area may be favorable for biogenic gas or CBNG. There is little information with which to make resource estimates.

Coalbed Natural Gas: Although the Cretaceous coals of the Alaska Peninsula province have wide aerial extent, Smith (1995) believes the variability of the coal development and discontinuous nature of the thin coal seams make large scale CBNG exploration difficult. Tertiary coals found above 5,000 ft in the Tolstoi Formation have high CBNG potential within the province (Smith 1995). The Bear Lake and Stepovak Formations have low CBNG potential due to their low rank coals.

5.3 GULF OF ALASKA ONSHORE BASIN

The following USGS conventional oil and gas play description for the Gulf of Alaska Tertiary basin is from Magoon et al. (1996).

Yakutat Foreland/Lituya Play (hypothetical): Reservoirs: Potential reservoir rocks are the same as in the Yakataga Fold Belt Play. Overall reservoir potential in any of the formations is most likely poor to fair at best. The depth range of potential lower Tertiary reservoirs is from about 1,500 ft to perhaps 30,000 ft. These estimates are based on well results for the minimum figure and on estimated depth to the base of Paleogene rocks immediately offshore for the maximum figure.

Source rocks: Source rocks are the same as in the Yakataga Fold Belt Play and would lie in the Paleogene sequence. Rocks of the Cretaceous Yakutat Group and the late Cenozoic Yakataga Formation have no source rock potential. No source rocks are known to be present in the Lituya Bay area. the Paleogene rocks found to the west are not known to be present in the Lituya Bay area either onshore or in the adjacent offshore.

Timing and migration: Generation and migration of hydrocarbons could have occurred anytime after deposition of the Paleogene strata, but may have occurred mostly during the late Cenozoic, concurrent with burial by the thick Yakataga Formation. The Dangerous River zone and the entire onshore region lie updip from the offshore Yakutat Terrane Basin axis. Thus, hydrocarbons generated in offshore Paleogene rocks during late Cenozoic burial could migrate updip into the onshore region. Some hydrocarbons have been generated; an exploratory well near Yakutat had oil and gas shows and still leaks a small amount of gas to the surface. Traps other than along the Dangerous River zone could be present beneath Yakutat Bay or the Malaspina area, perhaps created during early deformation of the Paleogene rocks.

Traps: Known or presumed potential traps lie largely along the Dangerous River zone. This feature developed in the early Tertiary, and traps could have formed either during the initial development or during subsequent deposition of strata against and over the zone. Few data are available from onshore to determine actual subsurface structure. Based on prior exploratory drilling, three traps are inferred. Two of these are gentle closures in Icy Bay (inferred from the Standard Oil Co. of California Rioux Bay number 1 well) and on the west side of Yakutat Bay (inferred from the Colorado Oil and Gas Corp. Malaspina 1A well). The third structure lies near the shoreline of the Yakutat Foreland, where seaward-dipping rocks are truncated and may be folded into anticlines, or where a footwall anticline could be present beneath a thrust fault. This area has been partly tested by three wells (Colorado Oil and Gas Corp. Yakutat 1, 2, and 3 wells). Other structures could be present along the continuation of the Dangerous River zone onshore or beneath Yakutat Bay and the Malaspina Glacier.

Exploration status: The play area is moderately explored. Ten wells and coreholes as deep as 13,800 ft have been drilled within the region on structures defined on seismic-reflection data. Further exploration depends on identifying subtle structural or stratigraphic traps, primarily along the Dangerous River zone, and also in the thick sedimentary rocks south and southwest of the Dangerous River zone. Further exploration would be warranted if significant accumulations of oil were found in the adjacent offshore, or if generation and migration of hydrocarbons from the thick offshore Paleogene sequences upward into the onshore sections could be shown or inferred to have occurred.

Coalbed Natural Gas: Most of the coals in the Gulf of Alaska onshore basin have been subjected to metamorphism resulting in intense compressional stresses and severe deformation (Smith 1995). This has driven existing hydrocarbons beyond the oil and gas generation window. Unmetamorphosed areas along the Gulf of Alaska coastline may be suitable for CBNG exploration.

6.0 OIL AND GAS DEVELOPMENT POTENTIAL

The potential for oil and gas development for the entire Ring of Fire planning area is shown in Map 5. This is a baseline scenario and projects development through the year 2020 on the assumption that all areas are open to development under standard lease terms and conditions except those areas closed by statute or for discretionary reasons.

Areas are assigned one of five ratings; high, medium, low, very low, and no known development potential. This projection is based on available data and professional judgment. The timing of the drilling and the areas receiving the greatest attention is difficult to predict. Actual development activity will be determined by accessibility to resources, including the perceived impact of lease stipulations by the petroleum industry; exploration and development costs; the success rate of wells drilled in the future; commodity prices; and production rates that provide an economically viable return on investment.

6.1 COOK INLET BASIN

The Cook Inlet Basin is a maturely developed basin that has produced oil and gas since 1957. The Cook Inlet region continues to be of interest to the petroleum industry. Although oil exploration and production are generally in decline, steady growth in the demand for natural gas within south central Alaska has stepped up exploration drilling for this resource.

The Beluga-Sterling Gas Play is a confirmed play for additional gas accumulations with 18 gas fields containing discovered reserves of 3.14 TCFG. The Beluga-Sterling Gas Play is classified as a heavily explored and developed area (over 1,100 exploratory, development and service wells) with **High** potential for the generation of gas and **High** development potential.

The Hemlock-Tyonek Oil Play is a confirmed play for additional oil accumulations with eight oil fields containing discovered reserves of 76 MMBO. The Hemlock-Tyonek Oil Play is classified as a heavily explored and developed area (over 1,100 exploratory, development and service wells) with **High** potential for the generation of oil and **High** development potential.

The Late Mesozoic Oil Play Play is classified as **High** potential for the generation of oil and **Low** development potential. This assignment is based on the poor reservoir rock quality where penetrated by wells and where it crops out within the basin.

Coalbed Natural Gas: CBNG in the Cook Inlet and Susitna basin is classified as a **High** potential for the generation of methane gas and **Moderate** development potential. CBNG is a major potential resource for south central Alaska with estimated technically recoverable resources of 7 Tcf. The highest potential occurs along the Castle Mountain Fault and along the uplifted basin margins. Montgomery (2003) is encouraged by early drilling results, the shallow coal depths (<5,000 ft), net coal thickness (>150 ft), and moderate gas content. However, the economic viability and timing of any contribution from this resource within the life of the plan is highly uncertain due to the high development costs, land access associated with split estate issues, the lack of sufficient data to predict production flow rates for gas, discouraging CBNG flow-test results to date, and the amount of produced formation water that must be properly disposed.

6.2 ALASKA PENINSULA PROVINCE

The Alaska Peninsula Mesozoic Play is classified as a moderately explored area (22 exploratory wells) with **High** potential for the generation of oil and gas and **Low** development potential. This assignment is based on the following factors: 1) the primary reservoir objective of this play (Upper Triassic limestone) has not been found in the wells that have penetrated this formation; 2) the two remaining potential reservoir rocks (Jurassic and Cretaceous sandstones) are lithic rich and have poor reservoir potential; and 3) the region currently lacks the production infrastructure to deliver exploited resources to market.

The Alaska Peninsula Tertiary Play is classified as a moderately explored area (nine exploratory wells) with **High** potential for the generation of oil and gas and **Low** development potential. This assignment is based on the lack of sufficient subsurface information. This region also lacks the production infrastructure to deliver exploited resources to market.

Coalbed Natural Gas: Tertiary coals within 5,000 ft of the surface in the Tolstoi Formation have **High** CBNG potential and **Low** development potential due to the lack of production infrastructure, high development costs, and land access issues. However, a local market may benefit from CBNG development should this resource be discovered in sufficient quantities near existing communities.

6.3 GULF OF ALASKA ONSHORE BASIN

The Yakutat Foreland/Lituya Play is classified as a moderately explored area (ten exploratory wells and core holes) with high potential for the generation of oil and gas and low development potential. This assignment is based on the following factors: 1) the reservoir potential likely poor to fair at best; 2) no source rocks are known to be present in the Lituya Bay area; 3) the Paleogene rocks to the west are not known to be present in the Lituya Bay area either onshore or in the adjacent offshore; and 4) the region currently lacks the production infrastructure to deliver exploited resources to market.

7.0 RFD BASELINE SCENARIO ASSUMPTIONS AND DISCUSSION

The following projections are based on past and present leasing, exploration, and development activity, as well as professional judgment on geological and related technological and economic factors. It is assumed that there will be no development or production in the Yakutat Forelands or the Alaska Peninsula Province for the life of the plan. This assumption is based on the lack of an oil or gas discovery within theses areas, the fact that no exploratory wells have been drilled during the past 20 years, and that exploration and development dollars in Alaska are likely to be spent on the North Slope and in the Cook Inlet Basin. The results of the State's proposed lease sale along the northern shore of the Alaska Peninsula in late 2005 may change this assumption.

7.1 PROJECTION OF OIL AND GAS LEASING ACTIVITY

Based on ADNR's Five Year Oil and Gas Leasing Program Schedule, DOG will conduct one lease sale a year from 2004 to 2008 within the Cook Inlet Basin area. In addition, DOG will also hold lease sales once a year in the Alaska Peninsula from 2005 to 2008. Should DOG continue this leasing trend, an additional 24 lease sales (one per year from 2009 through 2020, 12 in each area) would occur within both the Cook Inlet Region and the Alaska Peninsula.

It is assumed the remaining lands within the Ring of Fire planning area will not be offered for lease during the life of the plan based on current leasing trends by the state. However, the State has established a licensing program to encourage exploration in areas of Alaska where there is a higher investment risk to the operator. These areas have no existing infrastructure and have relatively low or unknown hydrocarbon potential. Within Ring of Fire planning area, two State exploration licenses have been issued in the Sustina Basin, west of the Parks Highway between Houston and Talkeetna. Exploration licensing gives an interested party the exclusive right to conduct oil and gas exploration. Once the work commitment has been met, e.g., exploration expenditures equal the amount of the winning bid, and if the licensee requests, the State will convert all or a portion of the remaining license area to standard oil and gas leases. The State recognizes the probability of commercial production on licensed lands is very low.

7.2 PROJECTION OF EXPLORATION

Based on the leasing scenario above and exploration activity in the Cook Inlet Basin from 1991 through 2003, it is assumed that at least one exploratory oil well would be drilled per year during the life of the plan. During this 13 year period, 11 oil exploration wells, or 0.85 wells per year, were drilled in the Cook Inlet Basin. Given the life of the plan (15 years), roughly 15 oil exploration wells would likely be drilled in Ring of Fire planning area throughout this timeframe.

Between 1973 and 2003, 18 gas exploration wells have been drilled in Ring of Fire planning area, averaging one gas exploration well drilled per year. However, 17 of these wells were drilled in the last 10 years, indicating a substantial increase in gas exploration in recent years. Should this rate of exploration continue, it is assumed that in the next 15 years, 26 gas exploration wells would be drilled throughout the Cook Inlet Basin.

Of the 114 exploration wells drilled in the basin through 2003, 87 were dry holes reflecting a 24 percent hydrocarbon discovery success rate. This rate increases to 55 percent for the last 10 years and is expected to remain relatively high due to continued improvements in geologic analysis, drilling and completion technology, and the use of advanced exploration technology such as three-dimensional (3-D) seismic surveys. Nondrilling exploration technologies, such as seismic surveys, increase the drilling success rate by identifying favorable areas for producing wells and excluding areas from consideration that have lower development potential. The use of these technologies decreases the number of unsuccessful wells drilled and may result in a net decrease in total wells drilled in an area, along with decreases in surface disturbances and other impacts associated with drilling. Should this success rate remain constant, it is assumed that in the next 15 years, 18 exploration wells would be dry holes, thus further reducing long-term disturbance as these pads and associated roads would be reclaimed.

Based on technology advances in recent years, such as improved drilling efficiencies through the use of 3-D seismic surveys, it is assumed five economic discoveries would be made and each would spur the development of a field (one oil field and four gas fields). To define the limits of the reservoir(s) after a discovery, three delineation wells would be drilled at each field.

7.3 PROJECTION OF DEVELOPMENT

From 1973 to 2003, 53 oil development wells have been drilled in the Cook Inlet Basin. Eleven of these wells, roughly one per year, were drilled in the last 10 years. Assuming this one-well-per-year trend continues, another 15 oil production wells would be drilled in the next 15 years.

In the same 30-year timeframe, 78 gas development wells, or roughly three wells per year, were drilled in the Cook Inlet Basin. Forty-one of these wells, roughly four per year, were drilled in the last 10 years. Assuming this four-wells-per-year trend continues, another 60 gas production wells would be drilled in the next 15 years.

Four of the 131 development wells drilled between 1973 and 2003 were dry holes. Of the 75 oil and gas development wells projected to be drilled during the life of the plan, two to three are assumed to be dry holes.

7.4 PROJECTION OF PRODUCTION

Appendix A displays oil, gas, and water production graphs within the Cook Inlet Basin. The graphs illustrate production rates from 1959 through 2004. They have been separated to display volumes of oil, gas, and water produced by reservoir, lessor (federal or state), and operator. Production rates have been calculated in mcf per day for natural gas, and bpd for oil and water by year (Porhola 2004). Using these past production curves, one could project a 15 percent declining production average per year. In doing so, gas production rates from the Tyonek Formation, for example, would fall from three mcf per day in 2004 to roughly 0.22 mcf per day by 2020. In general, oil and gas production will likely decline steadily through 2020. Figure 3 shows past and projected oil production curves for Alaska, including the Cook Inlet basin, through the year 2022 (ADNR/DOG 2004). Oil production in the Cook Inlet Region is projected to steadily decline through 2022.

Table 2 shows that production in Beaver Creek, Beluga River, Happy Valley, Kenai, McArthur River, Ninilchik, and North Cook Inlet will produce significant quantities of gas through the year 2020, while the Swanson River field will eventually cease production around 2017 (ADNR/DOG 2003)

Figure 4 illustrates gas price comparisons for past and future development in the Cook Inlet basin (Thomas et al. 2004). This figure illustrates Henry Hub gas prices falling to and maintaining a $4.50 per mcf price point through the year 2024, with Gulf Coast well head Average Estimated Output (AEO) rising to around $5.00 per mcf in 2014 and falling to around $4.00 per mcf in 2024.

Exploration wells are currently being drilled in the Beaver Creek and Swanson River Units. With oil and gas prices continuing to rise, future development will more than likely occur in those areas, as well as other areas throughout the Cook Inlet Basin. Aurora Gas believes there could still be up to one billion barrels of undiscovered recoverable oil reserves in the onshore of Cook Inlet (Petroleum News 2004). Aurora Gas is actively drilling in the Nicolai Creek unit on the west side of Cook Inlet. They have mapped five drillable prospects with unrisked expected recoverable reserves of 400 MMBO, and risked reserves of 140 MMBO.

Four of Aurora Gas oil prospects are located within 6 miles of existing oil pipelines, and two of these prospects have been defined by previously gathered 3-D seismic data. All prospects have good road access, which is spurring on Aurora Gas aggressive drilling campaign through the next two to three years. An estimated five to seven billion barrels of oil have been generated from the Middle Jurassic Tuxedni Group marine shales. In-place Cook Inlet oil reserves have been estimated to be at around 3.37 BBO. To date, nearly 1.35 BBO have been recovered from the Cook Inlet Basin.

Oil found to date largely follows three distinct south-southwest to north-northeast structural trends, namely the Trading Bay trend, the Middle Ground Shoal/Granite Point trend and the Swanson River trend. Aurora believes that by following logical extensions of these trends that they will discover and exploit new oil reserves. By expanding exploration patterns throughout the McArthur River and Swanson River fields, onshore oil discoveries could approach or equal past production rates.

7.5 PROJECTION OF RECLAMATION

Reclamation is an ongoing process throughout Ring of Fire planning area. Since 1901, 352 wells have been plugged and abandoned throughout Ring of Fire planning area (Flekenstein 2004). Should abandonment continue at this rate, roughly 161 wells would be plugged and abandoned throughout Ring of Fire planning area through 2020.

7.6 PROJECTION OF COALBED NATURAL GAS DEVELOPMENT

CBNG development in the Cook Inlet Basin would likely occur in areas that are currently the focus of CBNG exploration such as the Matanuska-Susitna Valley and the southern Kenai Peninsula near Homer. Although these locations are part of the mature Cook Inlet oil and gas basin, we consider this a frontier area regarding CBNG exploration due to limited exploration efforts to date in the Matanuska-Susitna Valley. These efforts, which began in the late 1990s, have included core sampling and the drilling of several pilot wells in bituminous coal seams of Tertiary age. The economic viability of the basin’s CBNG resources is highly uncertain because sufficient data on gas and water productivity does not exist.

BLM’s policy regarding RFD of fluid mineral resources in “frontier” areas requires that a minimum level of exploration and development activity be projected for the purpose of impact analysis. For these areas of low development potential, an assumption is made that a baseline discovery will involve certain exploration activity leading up to a discovery and subsequent development activity. According to BLM Handbook H-1624-1, which provides guidance on RFD development, "... projections should be based on past and present leasing, exploration, and development activity as well as professional judgment on geological and technological and economic factors. Extrapolations of historical drilling and/or production activity may be used as the basis for projections."

The potential coalbed natural gas in the Cook Inlet basin is estimated to be about 7 Tcf of technically recoverable resources, assuming 10 percent is accessible for production and a 50 percent recovery rate (Thomas et al. 2004). Unocal estimated the gas in place (GIP) of the Pioneer Unit, located in the Matanuska Valley, at 3.6 Tcf with recoverable reserves at 1.4 Tcf assuming a 40 percent recovery factor (Seamount et al. 2001). When a CBNG project is deemed economical to warrant full-scale production, many wells are often proposed. The number of wells is dependent upon several variables including: 1) number, thickness and depth of coal seams; 2) net coal thickness; 3) access; 4) amount of gas that could be recovered; 5) permeability and porosity; 6) produced water management; 7) the number of CBNG wells that can be served by a disposal well; and 8) disposal well depth.

Under this RFD scenario for CBNG production through 2020, recoverable reserves are assumed to be 1.4 Tcf and accessible from multiple coal seams. The Raton Basin, with estimated reserves of 1.88 Tcf, serves as the model for the predicted number of wells to be drilled in this RFD scenario. Table 3 shows the estimated resources and number of wells drilled for each of the Rocky Mountain CBNG basins.

Table 3. Rocky Mountain CBNG Basins

Basin	States	Producing Wells (1999)	Cumulative Production Thru 1999 (Bcf)	Estimated Resource (Tcf)	Average Per Well Production (mcfd)
San Juan	CO, NM	3,311	6,648	7.69	2,000
Powder River	WY, MT	1,657	120	10.04	200
Raton	CO, NM	405	68	1.88	250
Uinta	UT	370	121	3.81	625
Piceance	CO	40	35	11.55	140

(Lang 2002)

The field size would be similar in extent to the established Pioneer Unit, approximately 50,000 acres. To maximize recovery and minimize waste, a 100 acre well spacing pattern would be employed and 500 exploration wells (250 pads with two wells per pad) would ultimately be drilled. Ten percent of these wells would be abandoned as dry holes.

CBNG development generally involves a larger amount of surface disturbance than conventional oil and gas development due to the dispersed nature of CBNG well development (Table 4). CBNG wells require a network of access roads, drilling sites, pipelines, power lines, compressor stations, and containment ponds. Roads and utility corridors would be positioned to use existing disturbances as much as possible. Existing roads would be used as often as possible, and the gas field would be designed so that as many wells as possible can be serviced from each road. Roads to wells and compressor sites would be limited to single lane width with turnouts. Exploration wells would not have permanent gravel access roads. The operator would co-locate electric power, gas, and water lines with proposed roads when feasible to minimize overall disturbance. Power lines would be aboveground or buried per operator's plans.

Wells would be drilled with truck mounted water well type rigs capable of setting up on uneven terrain. Air is used to drill and remove the cuttings, instead of fluid, to reduce the volume of wastes to be buried on the well pad or hauled off site. A 100 square foot area would be bladed to accommodate the rig and a small reserve pit (6 ft by 15 ft by 15 ft). Wells drilled into different coal seams can be collocated on common well pads and it is assumed that a pad would contain two wells and produce from two different coal seams. Multiple seam completions in a single well bore would be encouraged to the extent technology permits. CBNG production could occur simultaneously from multiple seams or staggered over time from separate seams. During the early development phase, wells would be about 600 ft deep. Over time well depths would increase to more than 1,000 ft deep with a maximum depth of about 4,000 ft. Each pad would require about 1.75 acres; one acre for the pad (190 ft by 240 ft) and 0.75 acres for the access road. Part of the well pad area would be reclaimed for production operations and the entire area would be reclaimed when the well is plugged and abandoned. The long-term surface disturbance (10 to 20 years) at each productive well location where cut and fill construction techniques are used would encompass approximately 0.005 acres.

As wells are abandoned, the associated roads would remain open or be closed at the surface owner's discretion. If the roads were requested to be closed they would be rehabilitated. This includes leaving BLM and State surface roads open if access is desirable.

Wells would be completed using 7-inch steel well casing set and cemented to the surface from the top of the target coal bed. Small diameter tubing and an electric submersible pump would be installed in the well to bring the water to the surface. Once all wells have been drilled, produced water would be gathered and transported to injection wells for disposal. Wells determined to be productive would be shut-in until pipelines and other production facilities are constructed. If the well is determined not to be productive, it will be properly abandoned.

The average well discharge rate for a typical CBNG well is about 400 to 500 bbls of water per day. It is assumed the amount of water produced would not be the same for every well, and that water production would drop off rapidly over time, as the pressure within the coal seam falls and gas begins to flow freely. The early phases of high water production and low gas recovery would last for a period of six months to three years (Ogbe 2000). The produced water would be collected in a buried two-inch polyethylene flowline (pipeline) for transport to one of 23 water disposal facility locations (200 ft by 200 ft each). Pipeline trenches for well gathering lines are expected to disturb portions of 20- to 30-foot wide corridors temporarily and to be reclaimed as soon as practical after construction is completed. Trenches would be constructed along the access roads where possible. Separate gathering lines would be buried in the trenches and would transport methane gas to production pod facilities and produced water to disposal facility.

The water disposal facility would consist of four 400 bbl water tanks, a pump house, piping, and a well house. Those areas where elevation differences require supplemental pumping to transfer the produced water, transfer pumping stations (120 ft by 120 ft pads), consisting of a 400 bbl water tank with associated pump and piping, may also be needed. Water in the tanks would be separated from the gas and piped to a series of injections wells (water disposal wells) to subsurface aquifers geologically isolated from potential underground sources of drinking water. Disposal rates would be dependant on formation characteristics of the injection zones and in this scenario it is assumed that one injection well would service up to 20 CBNG wells (roughly 23 injection wells for the entire field).

Unlike conventional natural gas, CBNG has not generally required special treatment before sale –the gas is merely put through a dehydrator to remove remaining water and then injected into a pipeline. However, impurities would be removed before the gas is sent to a gathering system. Treatment depends on the nature of the produced gas, which is yet to be determined in the Valley.

Produced natural gas (methane) under wellhead pressure would move through the low pressure gas gathering system to a field compressor station (0.5 acres). On average, it takes one small compressor for every 10 to 20 wells to gather the gas prior to being piped to a larger pipeline. Under this RFD scenario the gas gathering system would consist of 45 pod stations, each serving ten CBNG wells, designed to raise the pressure from about 30 pounds per square inch (psi) to 150 psi. A one mile gathering line (approximately 25 ft wide), consisting of two polyethylene flowlines (one per well) would be buried from each pad to the field compressor. These lines would be laid in the travel routes to the wells and would follow the roads to the field compressors. The gas from each well is metered in the pod station and commingled prior to being piped to a larger (sales) compressor. Low-pressure steel lines would be laid from the field compressors to the dales compressor. One sales compressor (five acres) would service 15 pod stations to raise the pressure from 150 psi wellhead pressure to the ENSTAR pipeline pressure of about 800 psi.

Wellheads and metering equipment would be housed in 5-foot high fiberglass well covers painted an unobtrusive color and fenced to protect the facility from damage by wildlife. Electronic flow devices will measure natural gas production, and water will be measured through ultrasonic flow meters. A panel installed at the well starts and stops the pump based on fluid level measurement.

Table 4. Projected acreage disturbance due to CBNG exploration and development.

Facility	Development Phase			Operations
	Length	Width	Acres	Acres
New Roads	210 miles (mi)	15 ft.	382	322
Small Compressor Station (45)	110 ft	105 ft.	12	12
Gas and Water Lines	210 mi	25 ft.	636	636
Drill Pads (250; includes 12 injection wells)	190 ft	240 ft.	262	236
Large Compressor Station (3)	470 ft	470 ft.	15	15
Gas Lines (to sales line)	50 mi	25 ft.	151	130
Water Disposal Facility (23)	200 ft	200 ft.	21	21
Transfer Pumping Station (5)	120 ft	120 ft.	1.6	1.6
Total Disturbance			**1,480.6**	**1,373.6**

7.7 TYPICAL EXPLORATION, DEVELOPEMNT, PRODUCTION AND ABANDONMENT

To fully evaluate the surface disturbance impacts associated with projected oil and natural gas exploration and development in Ring of Fire planning area, the activities typical of these actions as they apply to south central Alaska are discussed below. Table 5 shows typical Alaska oil and gas activities and timeframes.

7.7.1 Geophysical Exploration

The likelihood of the presence of oil and gas is often determined by geological prospecting. Such prospecting can be done on the ground, where on and off-road vehicle travel may be necessary or by aerial survey. Exploration activities may include examination of the surface geology, geophysical survey programs, researching data from existing wells, and/or drilling an exploratory well. Surface analysis includes the study of surface topography or the natural surface features of the area, near-surface structures revealed by examining and mapping exposed bedrock, and geographic features such as hills, mountains, and valleys. Subsurface geology is not always accurately indicated by surface outcroppings. To verify surface indicators and to map the subsurface structures, geophysical exploration is used. An issued oil and gas lease is not required for geophysical exploration to occur; however, it may be permitted prior to or subsequent to leasing by bonded geophysical operators. Exploration activities may occur across the same area many times and continue over a period of years.

Geophysical companies usually conduct seismic surveys under contract with license holders. Contracts may have provisions that allow the geophysical company to sell the data to other interested companies. If sufficient data are already available, additional seismic data acquisition may not be necessary.

Geophysical exploration activities on federal lands in Alaska are regulated by 43 Code of Federal Regulations (CFR) 3151.2. BLM issues permits that include terms and conditions deemed necessary to protect values, mineral resources, and nonmineral resources including specific mitigating measures for public safety warnings, wildlife concerns, property protection (fences, wells, buried utility lines, etc.), and site reclamation. Restrictions in geophysical exploration permits depend on the duration, location, and intensity of the project.

Geophysical surveys help reveal what the subsurface geology may look like. There are three types of geophysical exploration: 1) gravitational field; 2) magnetic field; and 3) seismic characteristics. Gravitational prospecting detects variations in gravitational attraction caused by the differences in the density of various types of rock. Magnetic field methods reveal buried structures (likely to yield oil and gas) because such structures show a strong magnetic response. Magnetic prospecting often replaces or is used to supplement gravitational work. Both surveys consist of taking readings at regular intervals across the land from either hand held instruments, ground vehicles, or aircraft. No actual surface disturbance is involved unless off-road vehicle travel is used to reach survey points. These methods are used to get subsurface information over a large area.

Table 5. Typical Oil and Gas Activities and Timeframe

Project Phase	Duration (years)	Activities
Exploration	1 to 3	• geophysical permitting • environmental studies • seismic surveys to define prospects • well-site surveys and permitting • construct access roads/trails • temporary gravel pads • exploratory drilling • drill delineation wells (after discovery) • land clearing • work camp • water usage • increased air traffic • appraise and engineer reservoirs • drilling muds and discharges
Development	3 to 6	• permitting • identify gravel pits • construct gravel pads, and roads • dock and bridge construction • install drilling rigs • install pipelines • construct base camp • environmental monitoring • drill development wells • vehicle traffic to and from pads • drill re-injection wells • install production facilities and hookup
Production	10 to 30	• well workover (rigs) • pipeline maintenance • gravel pads and roads • produced water • air emissions • work camps • trucking
Abandonment	2 to 5 years per well	• plug and abandon wells • remove production equipment • dismantle facilities • decommission pipeline • restore and revegetate sites • phase out environmental monitoring

Seismic prospecting gives the most reliable and reproducible results. Companies will either gather two-dimensional (2-D) or 3-D seismic data.

Two-dimensional seismic programs usually require fewer personnel and use less equipment than 3-D programs. Generally, geophysical seismic lines are run on wide spacing intervals and are narrowed and concentrated in smaller geographic areas as the target area is better defined. Three-dimensional surveys tend to be used to delineate prospective areas rather than as exploratory tools in frontier areas. With a strong move towards 3-D surveys, 2-D has almost become a thing of the past. However, this is not the case in Alaska. Large areas that have been relatively unexplored can be mapped by acquiring large regional grids of 2-D seismic data that provide exploration teams with the information necessary to evaluate the regional geology and the potential hydrocarbon traps (Rice 1997).

Land-based seismic surveys are typically conducted during the winter months using truck-mounted vibrators or helicopters for remote operations. The method involves sending energy into the earth using an explosive charge or other energy wave-generating device, such as Vibroseis. Vibroseis generates energy waves of continuously varying frequency using metal plates lowered to the ground from beneath each vehicle. With the entire weight of the truck resting on the plate, a hydraulic system vibrates the plate, which transfers the energy into the ground. Depending on rock density, waves bounce back from the various formation layers and are received by listening devices called geophones arrayed along the line of survey. From two to eight trucks are used in tandem. Unless the topography is relatively flat and open, the trucks are restricted to existing roads and trails. An instrument truck equipped with a seismograph records the seismic information on a computer which is subsequently processed and displayed in the form of a seismic reflection profile. The Vibroseis technique works best on a hard surface, as a spongy surface does not transmit the output energy very well.

Explosives, although rarely used, are another way to impart energy into the ground for the seismograph to record. The explosives are lowered into drill holes and detonated, or they may be suspended on stakes above the ground to eliminate the need for drilling holes. The drill holes are drilled with either track-mounted drills or with drills slung into position by helicopters. For 3-D seismic operations, 4-inch diameter holes are drilled typically 25 ft deep with five pounds of explosive set at the base of the hole. Surface charge seismic involves placing explosive charges on the ground or above ground attached to wooden stakes some 3 ft high. In difficult terrain, both explosive methods may be used via helicopter to ferry people, materials, and instruments to the detonation points along the lines of survey. This eliminates surface impacts

7.7.2 Exploratory Drilling

If geologic studies indicate oil or gas may be present, lessees (an entity that owns the lease) may initiate drilling of an exploration well. Drilling is the only way to assess whether commercial quantities of oil or gas are present in subsurface rock formations. Drilling wells is expensive and exploratory drilling happens only after mineral rights have been secured, and after preliminary, less expensive exploration activities, such as seismic surveys, reveal the most likely places to find oil or gas. Exploratory drilling operations normally occur in winter to minimize impact. Sometimes temporary roads must be built to the area. Constructed access roads normally have a running surface (width) of approximately 12 ft and a right-of-way of 30 ft. These are low volume, single-lane roads built for a specific purpose or use and returned to a near natural condition upon completion of use. The length is dependent upon the well site location in relation to existing roads or highways.

The drill site is selected to provide access to the prospect to be drilled and, if possible, is located to minimize the surface area that may have to be cleared. A typical drill pad has dimensions of about 300 ft by 300 ft (two acres) and consists of a liner overlain by sand and gravel. Depending on the topography of the well site and access area, construction may require the creation of cut slopes and fill areas. The pad supports the drill rig, which is brought in and assembled at the site, a fuel storage area, and a camp for workers. If possible, an operator will use nearby existing facilities for housing and feeding its crew. If the facilities are not available, a temporary camp of trailers may be placed on the pad. Enough fuel is stored on-site to satisfy the operation's short-term need, which amounts to about 4,500 gallons of diesel and gasoline per day. The storage area is a diked gravel pad lined with 80-miles of synthetic membrane. Additional amounts of fuel may be stored at the nearest existing facility for transport to the drilling area as needed.

Byproducts of drilling activities include muds and cuttings, produced water, and associated wastes. Drilling employs the use of carefully mixed fluids, called muds. Cuttings are small fragments of rock up to an inch across that are dislodged and carried to the surface by drill muds. Drilling muds are maintained at a specific weight and viscosity and are mostly water-based mixtures of clay (bentonite) and other earthen materials designed to be environmentally benign. The muds are used to cool and lubricate the drilling bit, facilitate the drilling action, clean the bottom of the hole, flush out cuttings within the well bore, seal off porous zones in down-hole formations to prevent the flow of drilling fluids into these formations, and maintain reservoir pressure. Drilling mud is circulated through the drill pipe to the bottom of the hole, through the bit, up the bore of the well, and finally to the surface. When the mud emerges from the hole, it goes through a series of equipment used to screen and remove rock chips and sand-size solids. When the solids have been removed, the mud is placed into holding tanks and from the tanks it is pumped back into the well.

Chemicals may be added to maximize the effectiveness of drilling and casing. Oil-based muds and synthetic-based muds may also be used depending on the well depth, well diameter, and subsurface formations.

An exploratory drilling operation using water-based muds generates 7,000 to 13,000 bbls of waste per well, and depending on the depth and diameter of the well, 1,400 to 2,800 of those are cuttings (United States Environmental Protection Agency [USEPA] 1993). Oil-based mud volumes are generally less than water-based, because they are more efficient and oil-based muds may be reconditioned, reused, and re-sold. Newer synthetic-based muds produce less waste, improve drilling efficiency, are reusable, and have advantages in environmental protection over oil or water-based muds (Veil et al. 1999).

BLM and the State discourage the use of reserve pits and most operators now store drilling solids and fluids in tanks, or in temporary on-pad storage areas until they can be hauled out or injected down the annulus of the well in accordance with State of Alaska statute. A permit is required by the State for onsite disposal or storage of drill cuttings. Injection of ground up drill cuttings requires approval from Alaska Oil and Gas Conservation Commission (AOGCC). If a reserve pit is necessary, it is constructed off the drill pad in cut material or below ground level to prevent failure. The pit can be as large as 5 ft deep and 40 ft by 60 ft and is lined with an 80-mile liner to prevent contamination of surrounding soils.

Drilling mud and fluids produced from the well are separated and disposed of, often by reinjection at another facility. With appropriate permits, solids may be left in place in a capped reserved pit. If necessary, a flare pit may be constructed off of the drill pad to allow for the safe venting of natural gas that may be encountered in the well. If the exploratory well discovers oil or gas, it is likely that the gravel pad used for the exploratory well will also be used for development and production operations.

Exploratory drilling is conducted 24 hours a day because of rig-time costs. There are three 8-hour or two 12-hour shifts a day. Pickups or cars are used for workers' transportation to and from the well site.

The actual time to drill a well depends on several factors including the depth of the hole, the number and degree of mechanical problems, and whether it is a dry hole or a producer. One of the primary objectives of drilling an exploration well is the acquisition of downhole information. Formation evaluation covers a variety of data gathering and retrieving methods that include mud logging, wireline logging, formation testing, coring, and measurement while drilling (MWD) surveys. In wildcat wells (wells drilled outside of areas of established production or into deeper untested zones in established fields), it is important that quality data be obtained in order to justify the costly decision to run (or not run) production casing and complete the well.

Mud logging, conducted while the well is being drilled, evaluates the mud circulating back to the surface for the presence of hydrocarbons. Drilling will liberate even small amounts of hydrocarbons from sedimentary rock. The mud log is also used to record and describe the rocks that are encountered in the well.

Wireline logs provide indirect measurements of rock properties and are created by lowering instruments (the logging tool) into the well. They also are used to precisely determine the elevation and thickness of individual rock units or identify potential producing zones.

Formation testing (drill stem test [DST]) involves temporary completion of a well and measures the flow of hydrocarbons to determine whether or not commercial quantities exist in the formation being evaluated.

Coring obtains a whole sample of the subsurface rock by placing a special bit and core barrel at the end of the drill string and drilling a cylindrical sample of the rock. Core barrels are commonly 30 to 60 ft in length and are sent to a laboratory where it can be analyzed for certain properties such as porosity (space in the rock that is filled by fluids), permeability (the ability of the rock to transmit fluids), and the ratio of fluids present in the pores of the rock (oil, gas, and water).

The drilling process is as follows:

- Steel conductor casing, is set 60 ft into the ground.
- The bit rotates on the drill pipe to drill a hole through the subsurface rock formations.
- Blowout preventers are installed on the surface casing and only removed when the well is plugged and abandoned. Blowout preventers are large, high-strength valves that close hydraulically on the drill pipe to prevent the escape of fluids to the surface or into groundwater formations.
- Progressively smaller sizes of steel pipe, called casing, are placed into the hole and cemented in place to keep the hole from caving in, to seal off rock formations, and to provide a conduit from the bottom of the hole to the drilling rig.
- The well produces hydrocarbons, is shut-in, or is plugged and abandoned.

Upon completion of the drilling, the equipment is removed to another location. If hydrocarbons are not discovered in commercial quantities, the well is called a “dry hole.” The operator is then required to follow State and BLM policy procedures for plugging a dry hole. The drill site and access roads are rehabilitated in accordance with the stipulations attached to the approval of the well. If the exploratory well is successful, the operator will probably drill one or two more wells to delineate the extent of the discovery and gather more information about the field. The lessee needs to know how much oil and gas may be present, the quality, and the quality of the rocks in which they are found.

7.7.3 Development and Production

After the discovery of a successful well, additional exploratory wells may be needed for industry to make a decision on whether to develop the field. These additional wells can also provide meaningful information for land managers to help analyze potential impacts of field development and to make decisions based on more accurate information. Industry's decision to develop the field is essentially an economic one and may depend on the type of hydrocarbon present (i.e., oil or gas), the size and productivity of the geologic structure and formation, the distance from infrastructure, the price of oil or gas, and marketability. In some cases, a discovery may not be fully developed although production may take place to recoup some of the costs of exploration.

Once the presence of a reservoir is confirmed, the lessee may decide to pursue development of the reservoir (field) to fully extract the resource. The procedures for drilling development wells are about the same as for exploratory drilling except that there is less subsurface sampling, testing and evaluation. Field development locations are surveyed and a well spacing pattern established by the State with the concurrence of BLM on federal leases. The spacing between wells depends on the State's regulations and the type of hydrocarbon sought. Gas wells are usually spaced one per 640 acres and oil wells often 160 acres or 320 acres. In developed petroleum fields, there are about 2 miles of roads per 160 acres.

Many fields go through several development stages. A field may be considered fully developed and produce for several years and then new producing zones may be found. If commercial hydrocarbons are discovered in a new producing zone (reservoir) in an existing field, it is called a new pool discovery, as distinguished from a new field discovery. New pools can either be deeper or shallower than the existing producing zone and may lead to the drilling of additional wells. When sufficient development wells are completed, the production phase begins. Production allows the lessee to receive a return on investment through extraction, collection, and transportation of the resource to the marketplace. Depending upon reservoir characteristics, which affect the flow of oil and gas to the wellhead, additional development wells are drilled to extract the oil and gas.

After planning and designing the facility layout, the operator constructs gravel pads and drills production wells. To the extent permitted by the geologic target, the locations selected for well sites, tank batteries, pits, and pumping stations are planned so as to minimize long-term disruption of the surface resources. Design and construction techniques and other practices are employed to minimize surface disturbance and effects on other resources, and maintain the reclamation potential of the site. Site-specific geotechnical studies are conducted prior to any development activities to assess the local permafrost conditions. Structures, such as drill rigs and permanent facility buildings, are insulated to prevent heat loss into the ground.

A level drill pad, generally two to four acres in size, is needed to set up and operate the rig. Usually, the dimensions of a pad measure 350 ft by 450 ft, but this may be modified based on the number of wells to be drilled, the natural contours of the land and the other resource values involved. All of the pad must be placed on a "cut" rather than "fill" surface for reasons of safety and rig stability. Once the rig is set up, drilling takes place 24-hours per day, seven days a week. For all surface-disturbing activities, the topsoil is removed and stockpiled for redistribution over the disturbed area prior to reseeding of the site. Restoration of the area normally includes reseeding the area with native species, recontouring and drainage control.

Approximately 30 personnel are needed in drilling a typical well. Drilling may take from two weeks to six months to complete depending on the depth to be drilled. If no economic quantities of gas or oil are found it is considered a dry hole and the facilities are removed and the well pad is reclaimed along with the access road, unless it is needed for other purposes.

Firewalls/containment dikes are to be constructed and maintained around all storage facilities/ batteries. The containment structure must have sufficient volume to contain, at a minimum, the entire content of the largest tank within the facility/battery.

During drilling and after a well is in production, water comes to the surface mixed with oil and gas, and must be separated before further refining. Produced water contains mostly natural substances such as clay and sand, which is mixed with oil, water, and gas found in the subterranean strata. Produced waters are usually saline with some level of hydrocarbons. Associated wastes are other production fluids, such as tank bottom sludges, well work-overs, gas dehydration processes, tank wastewater, and other residues which are considered non-hazardous (low-toxicity) by the USEPA. Like drilling muds, chemicals may be added to produced water to remove harmful bacteria, halt corrosion, break up solids, prevent scale build up, and break oil/water emulsions.

Approximately 10,000 to 35,000 gallons of water a day may be needed for mixing drilling mud, cleaning equipment, and cooling engines. Water sources may be from wells, lakes, or streams. Drilling depths may range between 2,000 ft and 15,000 ft. Transporting and setting up a drill rig capable of reaching the deepest zones requires an access road sufficient to handle the 30 to 40 semi-trucks and trailers of heavy equipment and a daily traffic of 20 to 30 vehicles. These are low volume, single-lane roads, which may be reclaimed after a particular use terminates. These roads normally have a 12 to 14 foot travelway and connect terminal facilities, such as a well site, to collector, local, arterial, or other higher class roads.

Once production is established, pipelines and/or flow lines are constructed in conjunction with the construction of access roads whenever possible to minimize additional disturbance. Pipeline rights-of-way are generally less than 25 ft in width and follow existing rights-of-way where possible. Pipelines are trenched, backfilled, insulated (if buried), or elevated to permit movement of wildlife and to prevent undesirable thawing of permafrost. Pipelines are an economically feasible way to transport oil and gas onshore. Oil transportation by truck is sometimes used, but in many cases, is not economically feasible because of the low quantities of oil that can be transported and high labor costs. Production from multiple wells on one lease may be carried by flowlines to a central processing facility. Central processing and storage facilities can be used for multiple wells on the same contiguous lease or multiple wells in an established unit.

Production and processing equipment at a typical gas well location might consist of a wellhead, a production separator, a dehydrator, and tanks. The wellhead (or christmas tree) has valves used to control the flow of gas and liquids from the well. The gas must be separated from liquids in the production stream (water, gas condensates, or light crude oil) and is diverted to processing equipment on the location. During processing, a production separator removes most of the water and liquid hydrocarbons and a dehydrator removes any remaining water in the gas. The gas then goes through a metering facility and into a sales or gathering pipeline. All hydrocarbon liquids are placed into small tanks, <400 barrel; (one bbl equals 42 gallons) and subsequently trucked from the well site and sold or placed into a pipeline.

In order to move the gas through the pipelines gathering system, compression equipment is used. Field compression units are small and mobile and are sized for the amount of gas that needs to be moved. Gas from the field gathering lines may undergo further processing to remove hydrocarbon condensates and water to ensure the gas meets stringent transportation pipeline specifications. It is then fed into larger transportation lines, often at compressor stations along the route.

Natural gas, in many instances, needs more than simple well site processing due to impurities (e.g., hydrogen sulfide) or large amounts of non-flammable gases such as carbon dioxide. This separation process, which involves large volumes of gas from multiple wells, is conducted at facilities called gas plants. Sometimes the gas contains valuable heavier hydrocarbon compounds such as natural gas liquids (NGLs) that must also be processed out of the methane.

Production operations for natural gas generally include the following:

- Natural gas flows through a high-pressure separator system where liquids (water, condensate, etc.) are removed. Produced oil goes through a separator to remove the natural gas.
- The gas is compressed if necessary.
- The gas is dehydrated to remove any remaining water.
- The gas is metered (e.g., the amount of gas produced is measured).
- The gas is transported to a facility where it passes through a water precipitator to remove oil.

Typical oil well locations consist of a wellhead, pumping equipment, phase separation equipment, storage tanks, and a central processing facility (for multiple wells on the same lease or unit). Oil wells can be completed as flowing wells or pumping wells. Flowing wells have sufficient formation pressure to raise the oil to the surface. Insufficient formation pressure requires the oil to be pumped to the surface via: 1) pump jacks powered by internal combustion engines or electric motors, 2) submersible pumps, when large volumes of fluid have to be produced such as wells containing large amounts of water with the oil, 3) artificial lift or gas lift, where natural gas is pumped into a well to lift the fluids to the surface, or 4) hydraulic pumps where crude oil is pumped down one tubing string, activating a hydraulic piston and well fluids before returning to the surface in a second string or the casing annulus.

When the fluids reach the surface, the oil must be separated from the water and gas though the use of appropriate separation equipment. Large amounts of water are gravity-separated from the oil and routed into tanks for disposal. The remaining fluid is fed into heater-treaters, which separate the gas from the oil and also break apart water-in-oil emulsions that may occur during the production process. The casinghead gas, depending on the quantities produced, can be used on the lease, recovered and placed into pipelines for sale, or vented. After the separation process, oil and water are stored in tanks either at the location or at central processing facilities. The tanks can generally hold 400 to 500 bbls and any given tank battery will have varying numbers of tanks depending upon the productive capacity of the well. Tanks and separation vessels are placed within earthen berms or other containment structures in order to contain spilled fluids in case of an upset condition or rupture of a tank or vessel. Production equipment are required to be painted in colors that will blend into the surrounding environment. Popular colors are brown and green. Some or all of the facility must be fenced.

Production operations for oil generally consist of the following:

- Produced crude oil goes through a separator to remove gas from the oil stream.
- The oil moves to processing facility via a pipeline.
- The gas removed from the oil may be compressed and reinjected to maintain the pressure in the producing formation and assist in oil production.

As more wells are placed in production, roads are improved by regular maintenance, surfacing with gravel and installing culverts. Mineral materials (e.g., sand and gravel) are usually purchased from local contractors and obtained from federal sources. Materials that are obtained from areas of federally owned minerals require a sales contract and are processed through the field office where the materials occur. A new stage of field development can lead to changes in locations of roads and facilities. All new construction, reconstruction, or alterations of existing facilities-including roads, pits, flowlines, pipelines, tank batteries, or other production facilities must be approved by BLM.

If sufficient natural gas reserves are discovered and it is economically feasible, the gas could be made available to local communities through new pipelines. Gas may also be re-injected, as is done on the North Slope.

Pipeline depth must be at least 48 inches. When possible, a common point of collection shall be established to minimize the number of production sites.

The development "footprint" in terms of habitat loss or gravel filling has decreased in size in recent years as advances in drilling technology have led to smaller, more consolidated pad sizes. Longer horizontal departures reduce per acre impacts compared to older field developments. Depending on the depth of the reservoir rock and horizontal deviation ability, the area of surface disturbance per acre of habitat can be minimized. A single production pad and several directionally drilled wells can develop more than one, and possibly several, 640-acre sections. Based on current development practices, surface impact from developing tracts is unlikely to exceed 2 percent per 640-acre section for any given development on leased and developed acreage.

7.7.4 Plugging and Abandonment of Wells

If the well is a dry hole, the site is recontoured and the topsoil is spread over the disturbed area followed by seeding with native plants and grasses. If the well is a producer, that portion of the original pad needed to continue operations will remain unreclaimed for the life of the well (10 to 20 years).

The purpose of plugging and abandoning (P&A) a well is to prevent fluid migration between zones, to protect minerals from damage, and to restore the surface area. Each well has to be handled individually due to a combination of factors, including geology, well design limitations, and specific rehabilitation concerns. Therefore, only minimum requirements can be established initially, then modified for the individual well.

The first step in the P&A process is the filing of the Notice of Intent to Abandon (NIA). Both the Surface Management Agency (SMA) and BLM will review this. The NIA must be filed and approved prior to plugging a past producing well. Verbal plugging instructions can be given for plugging current drilling operations, but an NIA must be filed after the work is completed. If usable fresh water was encountered while the well was being drilled, SMA will be allowed, if interested, to assume future responsibility for the well and the operator will be reimbursed for the attendant costs.

The operator's plan for plugging the hole is reviewed. The minimum requirements are: in open hole situations, cement plugs must extend at least 50 ft above and below zones with which has the potential to migrate, zones of lost circulation (this type of zone may require an alternate method to isolate), and zones of potentially valuable minerals. Thick zones may be isolated using 100-foot plugs across the top and bottom of the zone. In the absence of productive zones and minerals, long sections of open hole may be plugged with 150-foot plugs placed every 2,500 ft. In cased holes, cement plugs must be placed opposite perforations and extending 50 ft above and below except where limited by plug back depth.

A permanent abandonment marker is required on all wells unless otherwise requested by SMA. This marker pipe is usually at least 4 inches in diameter, 10 ft long, 4 ft above the ground, and embedded in cement. The pipe must be capped with the well identity and location permanently inscribed.

The SMA is responsible for establishing and approving methods for surface rehabilitation and determining when this rehabilitation has been satisfactorily accomplished. Possibilities may exist for developing a well for fresh water purposes, utilizing improvements, or making wildlife habitat improvements. Reclamation criteria include: 1) final configuration of the disturbed area; 2) stabilization of the soil; 3) management of the topsoil and addition of appropriate fertilizers; 4) revegetation with prescribed seed mixtures; 5) air, water, and visual quality standards; 6) compliance inspection intervals and bond amounts; and 7) conditions for bond release. At this point, a Subsequent Report of Abandonment can be approved.

7.7.5 Coalbed Natural Gas Development

Drilling for CBNG is very similar to drilling for conventional oil and gas except that generally smaller drilling rigs are used since, at present, CBNG resources are generally at much shallower depths on average than oil and gas. CBNG development also involves a larger amount of surface disturbance than conventional oil and gas development. CBNG ancillary facilities include access roads, pipelines for gathering gas and produced water, electrical utilities, facilities for treating and compressing gas and disposing of produced water, and pipelines for delivering gas under high pressure to transmission pipelines.

Unlike conventional gas, CBNG does not usually require additional treatment or processing before use. The gas is piped from the wellhead to a commercial gas line for direct distribution to homes and businesses. Typical surface disturbance associated with a producing CBNG pad is around 1 acre (ALL Consulting and Montana Board of Oil and Gas Conservation 2004). Surface disturbance would also include construction of off channel water storage, battery sites of about 2 acres each, one high-pressure compressor site of approximately 10 ten acres, and access roads (0.75 acres per pad), pipelines, and electric lines needed to service the wells.

Wells to be drilled on shared sites with up to four wells (one per coal bed) may be located on a common well site. The operator should co-locate electric power, gas, and water lines with proposed roads as much as possible to minimize overall disturbance. CBNG production produces large volumes of water of varying quality for which two disposal methods exist–

surface disbursal or re-injection. Average well discharge for a typical CBNG well is around 12 gallons per minute, or just over 17,000 gallons per day.

Wells are drilled with truck mounted water well type rigs. Because this type of rig can be set up on uneven terrain, the surface is generally not bladed or a pad site constructed unless topography requires it. The drilling and completion operation for a CBNG well normally requires a maximum of 10 to 15 people at a time, including personnel for logging and cementing activities. A 100 ft square area is typically mowed to accommodate the rig and small reserve pits, about 6 ft by 15 ft by 15 ft are constructed to serve all of the drilling wells on that site. A total of about 1 acre is required for the two to five wells drilled on a site (the actual number of wells per site depends upon the number of coal seams to be developed at that site). Wells are completed using 7-inch steel well casing set and cemented to surface from the top of the target coal bed. Small diameter tubing and an electric submersible pump would be installed in the well. Topsoil is stripped and saved from any surface disturbing operation and used for reclamation of the disturbed area (BLM 2003).

The operator will use existing roads and trails to the extent possible. An average of 15 miles or less of new gravel roadways would generally be used for this project. Electrical power and water and gas flow lines will generally follow the road system and, to the extent possible, will use the same right-of-way. Power lines will be plowed in if possible to minimize surface disturbance.

Wellheads will be equipped with 5-foot frost boxes painted an unobtrusive color and fenced to protect the facility from damage by wildlife. Electronic flow devices will measure natural gas production and water will be measured through ultrasonic flow meters. A panel installed at the well starts and stops the pump based on fluid level measurement. Any interested companies must submit a surface use plan, water management plan, and reclamation plan as required in the BLM Onshore Oil and Gas Order Number 1 (BLM 1983).

8.0 SURFACE DISTURBANCE DUE TO OIL AND GAS ACTIVITY ON ALL LANDS

Type of Action	Number of Actions	Area Disturbed[1]	Short Term Disturbance (acres)	Long Term Disturbance (acres)
Geophysical Exploration (miles)	*1,000*	*Using existing roads, old seismic line trails and off-road trails (1 acre per mile)*	*1,000*[2]	*Minimal*
Oil Exploration Wells	15	Drill pads and access road	67[3]	7[4]
Gas Exploration Wells	26	Drill pads and access road	304[3]	48[4]
Coalbed natural gas (CBNG) Gas Wells	500	Drill pads (2 wells per pad) access road,	604[5]	28[6]
Delineation gas wells (offsetting exploration wells)	12	Drill pads, access road, pipelines and utilities	155[7]	155
Gas development Wells	60	Drill pads (5 wells per pad), access road, pipelines and utilities	96[7]	96[8]
Delineation oil wells (offsetting exploration wells)	3	Drill pads, access road, pipelines and utilities	39[9]	39
Oil development Wells	15	Drill pads (3 wells per pad), access road, pipelines and utilities	36[9]	36[9]
Gas separation equipment and compression Facilities	4	Pads, access road, pipelines and utilities	20[10]	20
CBNG Field Compressor Station	45	Pads, access road, gathering pipelines and utilities	534[11]	534
CBNG Sales Compressor Station	3	Pads, access road, pipelines and utilities	76[12]	76
CBNG Gas Lines (miles to sales line)	50	Pipeline: 3 acres initial disturbance per mile, 2.6 acres stabilized per mile	152[13]	152
CBNG Water Disposal Facility	23	Pads, access road, pipelines and utilities	106[14]	106
Conventional Gas transmission pipeline (miles)	120	3 acres initial disturbance per mile; 2.6 acres stabilized per mile	360[15]	312
CBNG Transfer Pumping Station	5	Pads, access road, pipelines, and utilities	9[16]	9
Total Acres Disturbed by Exploratory Drilling, Development and Production			**2,558**	**1,910**

NOTES:

1. Acreage estimates for each component from observed disturbance in Kenai Peninsula area of the Cook Inlet Basin unless otherwise noted.
2. Geophysical exploration (italicized) is not included in the total acres disturbed because it is temporary and minimally intrusive on the environment. Geophysical exploration requires a discretionary approval that is not associated with leasing and subsequent activities.
3. Exploration well – assume 2 acres (300 feet by 300 feet) for drill pad (including worker camp) and for oil wells at 160 acre spacing; 0.5 miles of roads per well by 40 ft width by 15 wells equals 67 acres (30 acres plus 37 acres); for gas wells at 460 acre spacing; 2 miles of roads per well by 40 ft width by 26 wells equals 304 acres (52 acres plus 252 acres).
4. All exploration well pad acreage is reclaimed within two seasons, excluding five discovery wells that are developed into production wells (18 dry holes and 18 non-economic discovery wells by 2 acre pad equals 72 acres reclaimed). It is assumed that access roads are not reclaimed immediately.
5. 500 CBNG wells (2 per pad) – assume 1 acre per pad by 250 pads equals 262 acres; 188 miles of access roads (0.75 miles per pad by 250 pads) by 15 ft. width equals 342 acres.
6. Assume 10 percent dry holes; 50 wells or 25 pads reclaimed immediately (includes 19 miles of access road reclamation). Producing CBNG wells – assume 1 acre per producing well not to be reclaimed immediately.
7. Delineation and development gas wells – assume 3.2 acres (350 feet by 400 feet) per drill pad; 2 mile access road per delineation well by 40 ft width by 12 wells equals 116 acres; assume 4 new gas fields; 3 pads and 15 development wells per field (five development wells per pad); 1 mile access road per development pad by 40 ft width by 12 pads equals 58 acres; 3 acres for associated pipelines and power lines per pad (25 ft utility width by 1 mile per pad by 12 pads equals 36 acres. One exploration well would be used as a worker camp, if needed.
8. Assume nine gas development wells drilled are sub economic.
9. Delineation and development oil wells – assume 3.2 acres (350 by 400 feet) per drill pad; 2 mile access road per delineation well by 40 ft width by three wells equals 29 acres; assume one new oil field; five pads and three development wells per pad; 0.5 mile access road per development pad by 40 ft width by five pads equals 12 acres; assume two development wells drilled are sub economic, 1.5 acres for associated pipelines and power lines per pad (25 ft utility width by 0.5 mile per pad by 5 pads equals 8 acres. One exploration well would be used as a worker camp, if needed.
10. Assume one gas compression facility for each of the four gas field discoveries (5 acres each).
11. CBNG field compressor station (0.5 acres each); assume 0.75 miles of plastic low-pressure gathering lines per pad (225 pads) by 25 ft utility width (parallels pad access road) equals 511 acres; 511 acres plus 23 acres equals 534 acres.
12. CBNG sales compressor station (5 acres each); assume 20 miles of steel low-pressure gathering lines by 25 ft utility width (parallels field compressor access road) equals 61 acres; 61 acres plus 15 acres equals 76 acres.
13. 25 ft corridor from sales compressors to high pressure sales line.
14. Assume 1 acre per pad by 23 pads equals 23 acres; 17 miles of access roads (0.75 miles per pad by 23 pads) by 15 ft width equals 31 acres; assume 0.75 miles of plastic low-pressure gathering lines per pad (23 pads) by 25 ft utility width (parallels pad access road) equals 52 acres; 52 acres plus 23 acres plus 31 acres equals 106 acres.
15. Gas transmission pipelines 3 acres per mile (25 feet wide) and reclaim to approximately 2.6 acres (22 feet) wide; 3 acres/miles x 120 miles equals 360 acres; 2.6 acres/mile x 120 miles equals 312 acres.
16. 5 pads (120’ by 120’) equals 1.7 acres; 7 miles of access roads (0.75 miles per pad by 5 pads) by 15 ft width equals 342 acres.

9.0 BIBLIOGRAPHY

Adkison, W.L., Kelley, J.S., and Newman, K.R., l975b, Lithology and palynology of the Beluga and Sterling Formations exposed near Homer, Kenai Peninsula, Alaska: U. S. Geological Survey Open-File Report 75-383, 239 p.

Alaska Economic Information System - Department of Community & Economic Development; Kenai Peninsula Borough: Economic Overview (publishing date unknown).

Allen, R., 2001. Coalbed methane primer, www.landman.org/ann_papers/allen.doc

ALL Consulting and Montana Board of Oil and Gas Conservation, 2004. Coal Bed Methane Primer, New Source of Natural Gas – Environmental Implications: Background and Development in the Rocky Mountain West, U.S. Department of Energy National Petroleum Technology Office, 60 p.

ALL Consulting, Tulsa, OK and Montana Board of Oil and Gas Conservation, Billings MT; April 2002. Handbook on Best Management Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin, p.

Atwood, W.W., 1911. Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geological Survey Bulletin 467, 137 p.

Barnes, F.F., 1967. Four preliminary gravity maps of parts of Alaska: U.S. Geological Survey Open-file Report 278, 5 p.

Barnes, F. F., and Payne, T. G., 1956a. The Wishbone Hill District, Matanuska coal field, Alaska, U. S. Geological Survey Bulletin 1016, 88 p.

Barnes, F. F., and Payne, T. G., 1956b. The Wishbone Hill District, Matanuska coal field,Alaska, U. S. Geological Survey Bulletin, 1016, 85 p.

Bayer, K. C., Mattick, R. E., Plafker, G., and Bruns, T. R., 1977, Refraction studies between Icy Bay and Kayak Island, eastern Gulf of Alaska: U.S. Geological Survey Open-File Report 77-550, 45 p.

Beikman, H. M., 1980. Geologic map of Alaska: U. S. Geological Survey, 1 sheet, 1:1,000,000.

Bergquist, H.R., 1961. Early Cretaceous (Middle Neocomian) microfossils in south-central Alaska, in Geological Survey research 1961: U. S. Geological Survey Professional Paper 424-D.

Bird, K. J., and Magoon, L. B., 1988. National assessment of undiscovered conventional oil and gas resources: U. S. Geological Survey Open-File Report 88-373, p. 212-220.

Blasko, D.P., 1976. Oil and gas seeps in Alaska: Alaska Peninsula, western Gulf of Alaska: U.S. Bureau of Mines Report Inventory 8122, 78 p.

Boss, R.F., Lennon, R.B., and Wilson, B.W., 1976. Middle Ground Shoal oil field, Alaska, in Braunstein, Jules, ed., North American oil and gas fields: American Association of Petroleum Geologists Memoir 24, p. 1-22.

Brooks, A.H., 1918. The Alaskan mining industry in 1916: U. S. Geological Survey Bulletin 662, pp 11-62.

Brooks, A.H., 1922. The Alaskan mining industry in 1920: U. S. Geological Survey Bulletin 722, pp 7-67.

Brooks, A.H., 1925. Alaska's mineral resources and production, 1923: U. S. Geological Survey Bulletin 773, pp 3-52.

Bruns, T.R., Fisher, M.A., Magoon, L. B., Molenaar, C.M. and Valin, Z.C., 1995. Southern Alaska 1995 Geologic Report, 23p.

Bruns, T. R., 1988. Petroleum geology and hydrocarbon plays of the Gulf of Alaska onshore province: A report for the National Hydrocarbon Assessment program: U.S. Geological Survey Open-File Report 88-450J, 30 p.

Bruns, T.R., 1995. Gulf of Alaska, *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources--Results, methodology, and supporting data: U. S. Geological Survey Digital Data Series 30, one CD-ROM.

Bruns, T. R., and Plafker, George, 1982. Geology, structure and petroleum of the southeastern Alaska and northern Gulf of Alaska continental margins, in Bruns, T. R., ed., Hydrocarbon resource report for proposed OCS lease sale 88; southeastern Alaska, northern Gulf of Alaska, Cook Inlet, and Shelikof Straits: U.S. Geological Survey Open-File Report 82-0928, p. 11-13.

Bureau of Land Management in Cooperation with the USDOI Minerals Management Service, 2003. Northwest National Petroleum Reserve – Alaska, Final Integrated Activity Plan/Environmental Impact Statement, USDOI, Volume One, Section IV, 557p.

Burk, C.A., 1965. Geology of the Alaska Peninsula-Island Arc and continental margin: Geological Society of America Memoir 99, 250 p., scales 1:250,000 and 1:500,000, 3 sheets.

Calderwood, K.W., and Fackler, W.C., 1972. Proposed stratigraphic nomenclature for Kenai Group, Cook Inlet Basin, Alaska: American Association of Petroleum Geologists Bulletin, v. 56, no. 4, p. 739-754.

Capps, S.R., 1923. The Cold Bay District: U. S. Geological Survey Bulletin 739, pp 77-116.

Churkin, Michael, Jr., 1973. Paleozoic and Precambrian rocks of Alaska and their role in its structural evolution: U.S. Geological Survey Professional Paper 740, 64 p.

Conwell, C.N., and Triplehorn, D.M., 1978. Herendeen Bay-Chignik coals, southern Alaska Peninsula: Alaska Division of Geological and Geophysical Surveys Special Report 8, 15 p, 2 plates, scale 1:125,000 approximately.

Detterman, R.L., 1978. Interpretation of depositional environments in the Chignik Formation, Alaska Peninsula, Johnson, K.M., ed., The United States Geological Survey in Alaska: Accomplishments during 1977: U. S. Geological Survey Circular 0772-B, pp B62-B63.

Detterman, R. L., Case, J. E., and Wilson, F. H., 1979. Paleozoic rocks on the Alaska Peninsula, in Johnson, K.M., and Williams, J. R., eds., The United States Geological Survey in Alaska--Accomplishments during 1978: U.S. Geological Survey Circular 804-B, p. B85-B86.

Detterman, R.L., Allaway, W.H., Jr., O'Leary, R.M., Gruzenski, A.L., Hurrell, J.T., and Risoli, D.A., 1980. Sample location map and analytical data for rock samples collected in 1979, Ugashik and Karluk quadrangles, Alaska: U. S. Geological Survey Open-file Report 80-142, 1 sheet, scale 1:250,000.

Detterman, R.L., and Hartsock, J.K., 1966. Geology of the Iniskin-Tuxedni Region, Alaska: U.S. Geological Survey Professional Paper 512, 78 p.

Detterman, R.L., Miller, T.P., Yount, M.E., and Wilson, F.H., 1981. Geologic map of the Chignik and Sutwik Island quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-1229, scale 1:250,000.

Doughty, Tom C. Faulder, David D. Hite, David M. Thomas, Charles P., 2004. South-Central Alaska Natural Gas Study. U. S. Department of Energy, National Energy Technology Laboratory, Arctic Energy Office, 21p.

Ehm, Arlen, 1983. Oil and gas basins map of Alaska: Alaska Division of Geological and Geophysical Surveys Special Report 32, 1 sheet, scale 1:2,500,000.

Evergreen Resources, Inc. Webpage, 2004. (http://www.evergreen-res.com/alaskaprofile.html), 1p

Hite, D.M., 1976. Some sedimentary aspects of the Kenai Group, Cook Inlet, Alaska, in Miller, T.P., ed., Recent and ancient sedimentary environments in Alaska: Alaska Geological Society, Anchorage, Alaska, p. I1-I23.

Imlay, R.W., 1981. Early Jurassic Ammonites from Alaska: U.S. Geological Survey Professional Paper 1148, 40 p., plates.

Jones, D.L., and Detterman, R.L., 1966. Cretaceous stratigraphy of the Kamishak Hills, Alaska Peninsula, in Geological Survey research 1966: U.S. Geological Survey Professional Paper 550-D, p. D53-D58.

Jones, D.L., Silberling, N.J., Berg, H.C., and Plafker, George, 1981. Map showing tectonostratigraphic terranes of Alaska, columnar sections, and summary description of terranes: U.S. Geological Survey Open-file report 81-792, 20 p., 2 sheets.

Knappen, R.S., 1929. Geology and mineral resources of the Aniakchak district: U.S. Geological Survey Bulletin 797, pp 161-226.

Keller, A., and Reiser, H.N., 1959. Geology of the Mount Katmai area, Alaska: U.S. Geological Survey Bulletin 1058-G, p. G261-G268.

Kellum, L.B., Davies, S.N., and Swinney, C.M., 1945. Geology and oil possibilities of the southwestern part of the Wide Bay anticline, Alaska: U. S. Geological Survey Open-file Report 34, 17 p.

Kennedy, G.C., and Waldron, H.H., 1955. Geology of Pavlof Volcano and vicinity, Alaska: U.S. Geological Survey Bulletin 1028-A, pp 1-19.

Grantz, Arthur, Jones, D.L., and Lanphere, M.A., 1966. Stratigraphy, paleontology, and isotopic ages of upper Mesozoic rocks in the south- western Wrangell Mountains, Alaska: U. S. Geological Survey Professional Paper 550-C, p. C39-C47.

Hayes, J.B., Harms, J.C., and Wilson, Thomas, Jr., 1976. Contrasts between braided and meandering stream deposits, Beluga and Sterling Formations (Tertiary), Cook Inlet, Alaska, in Miller, T.P., ed., Recent and ancient sedimentary environments in Alaska: Alaska Geological Society, p. J1-J27.

Lang, Karl, 2002. Options for Coalbed Methane Water Management, Petroleum Technology Transfer Council, Network News Vol. 8, No. 1, First Quarter 2002.

Keller, A.S., and Reiser, H.N., 1959. Geology of the Mount Katmai area, Alaska: U.S. Geological Survey Bulletin 1058-G, pp 261-298.

Kirschner, C.E., and Lyon, C.A., 1973. Stratigraphic and tectonic development of Cook Inlet petroleum province, in Pitcher, M.G., ed., Arctic geology: American Association of Petroleum Geologists Memoir 19, p. 396-407.

Kremer, M.C., Stadnicky, G., 1985. Tertiary stratigraphy of the Kenai Peninsula - Cook Inlet region, in Sission, A., ed., Guide to the Geology of the Kenai Peninusla, Alaska: Alaska Geological Society, P.O. Box 101288, Anchorage, p. 24-42.

Kruuskra, V.A., and Boyer, C.M., Jr., 1993. Economic and parametric analysis of coalbed methane, *in* Law, B.E. and Rice, D.D., Hydrocarbons from Coal; American Association of Petroleum Geologist Studies in Geology No. 38; Tulsa, Oklahoma; p.373-394.

Lyle, W.M., Morehouse, J.A., Palmer, I.F., Jr., and Bolm, J.G., 1979. Tertiary formations and associated Mesozoic in the Alaska Peninsula area, Alaska, and their petroleum-reservoir potential, Alaska Division of Geological and Geophysical Surveys Geologic Report 62, 65 p., 19 plates.

Mancini, E.A., Deeter, T.M., and Wingate, F.H., 1978. Upper Cretaceous arc-trench gap sedimentation on the Alaska Peninsula: Geology, v. 6, No. 7, pp 437-439.

Marathon Oil Company Alaska Production Region, 2003. Marathon Oil Company Exploration and Production in the United States, Alaska, http://www.marathon.com/Our_Business/Marathon_Oil_Company/Exploration_Production/United_States/Alaska/, 1p.

Magoon, L.B., Molenaar, C.M., Bruns, T.R., Fisher, M.A., and Valin, C.Z., 1996. Region 1, Alaska, Geologic Framework, *in* Gautier, D. L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., National Assessment of United States Oil and Gas Resources--Results, Methodology, and Supporting Data: U.S. Geological Survey Digital Data Series DDS-30, Release 2, p. 1-14.

Marlow, M.S., Gardner, J.V., Vallier, T.L., McLean, H., Scott, E.W., and Lynch, M.B., 1979. Resource report for proposed OCS Lease Sale No. 70, St. George Basin, Shelf Area, Alaska: U. S. Geological Survey Open-file Report 79-1650, 79 p.

Martin, G.C., 1905. Notes on the petroleum fields of Alaska in Report on progress of investigations of mineral resources in Alaska in 1904, ed. A. H. Brooks: U.S. Geological Survey Bulletin 259, p. 128-139.

Martin, G.C., 1921. Preliminary report on petroleum in Alaska: U.S. Geological Survey Bulletin 719, 83 p.

Martin, G.C., 1926. The Mesozoic stratigraphy of Alaska: U.S. Geological Survey Bulletin 776, 493 p.

McLean, H., 1979. Observations of the geology and petroleum potential of the Cold Bay-False Pass area, Alaska Peninsula: U.S. Geological Survey Open-file Report 79-1605, 34 p.

Merritt, R.D., Eakins G.R., and Clough, J.G., 1982. Coal investigations of the Susitna Lowland, Alaska: Alaska Division of Geological and Geophysical Surveys Open-file Report 142, 89 p., 4 sheets, scale 1:250,000.

Miller, D.J., 1975. Geologic map and sections of the central part of the Katalla District, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-722.

Miller, D.J., Payne, T.G., and Gryc, George, 1959. Geology of possible petroleum provinces in Alaska: U.S. Geological Survey Bulletin 1094, 131 p.

Moffit, F.H., 1927. Mineral industry of Alaska in 1925: U.S. Geological Survey Bulletin 792, pp 1-39.

Montgomery, S.L., Barker, C.E., Seamount, D., Dallegge, T.A., and Swenson, R.F., 2003. Coalbed Methane, Cook Inlet, South-central Alaska: A potential giant gas resource: American Association of Petroleum Geologists Bulletin, Vol. 87, N0. 1, pp. 1-13.

Ogbe, David, 2000. Guidelines for Designing Water Guidelines for Designing Water Disposal Systems for Coalbed Methane Production in Alaska, Presented March 3, 2000 – West Coast PTTC Workshop Anchorage, AK.

Onshore Oil and Gas Order No. 1, 1983. Approval of Operations on Onshore Federal and Indian Oil and Gas Leases, U.S. Department of the Interior, Bureau of Land Management, 10 p.

Plafker, George, 1971. Possible future petroleum resources of Pacific-margin Tertiary basin, Alaska, in Future petroleum provinces of North America: American Association of Petroleum Geologists Memoir 15, p. 120-135.

Rice, Shawn, 1997. On-shore geophysical exploration: Anchorage, Alaska Science, Traditional Knowledge, and the Resources of the Northeast Planning Area of the National Petroleum Reserve-Alaska., NPR-A Symposium Proceedings, April 16-18, 1997 Anchorage, Alaska.

Richter, Donald H., Wilson, Frederic H., Labay, Keith A., and Preller, Cindi C., 2002. Abstract - Geologic Map of Wrangell-Saint Elias National Park and Preserve, AK; 1 sheet.

Seamount, D, Sullivan, F., Brandenburg, T., Crandall, R., Tabler, K., Downey, R., Childers, D., Carson, S., Smith, L., Barker, C., Thomas, D., Cross, R., and Pavia, G., 2001. West Coast PTTC Workshop Anchorage, AK.

Smith, P.S., 1929. Mineral industry of Alaska, in 1926: U.S. Geological Survey Bulletin 797, pp 1-50.

Smith, T. N., 1995. Coalbed methane potential for Alaska and drilling results for the upper Cook Inlet basin, Intergas ’95 proceedings, May 15-19, 1995, 21 p.

Smith, T.N., and Clough, J.G., 1993. Coalbed methane potential for Alaska: 1993 American Assoc. of Petroleum Geologists Annual Convention Program, abs. p. 184.

Smith, P.S., 1939. Areal geology of Alaska: U.S. Geological Survey Professional Paper 192, 100 p.

Smith, W.R., and Baker, A.A., 1924. The Cold Bay-Chignik district, Alaska: U.S. Geological Survey Bulletin 755, pp 151-218.

State of Alaska, 2002. Alaska Oil and Gas Conservation Commission Annual Report, Alaska Oil and Gas Conservation Commission, 347 p.

Tesoro National Website, 2004. Refining and Marketing – Kenai, AK, MC2 Studios, Inc., http://www.tesoropetroleum.com/kenai.html, 1p.

Thomas, C.P., Doughty, T.C., Faulder, D.D., Hite, D.M., 2004. Department of Energy, 2004, South-Central Alaska Natural Gas Study, U.S. Department of Energy, National Energy Technology Laboratory, Arctic Energy Office, DE-AM26-99FT40575, 207 p.

URS Corporation, 2005. Mineral potential report - Ring of Fire Planning Area, Alaska, Unpublished report prepared for the Bureau of Land Management, Anchorage Field Office, Alaska, 68 p.

U.S. Department of the Interior, 1989. Oil And Gas Surface Operating Standards For Oil And Gas Exploration And Development; Bureau of Land Management and U.S. Department of Agriculture – Forest Service Rocky Mountain Regional Coordinating Committee (RMRCC), Third Edition, 45 p.

U.S. Fish and Wildlife Service, 1985. Kenai National Wildlife Refuge Final Comprehensive Conservation Plan-Environmental Impact Statement-Wilderness Review, United States Fish and Wildlife Service, 195 p.

U.S. Geological Survey, 1995. Circular 1118 by U.S. Geological Survey, 1995, National Assessment Of United States Oil And Gas Resources, Overview of the 1995 National Assessment of Potential Additions to Technically Recoverable Resources of Oil and Gas-Onshore and State Waters of the United States, National Oil and Gas Resource Assessment Team, 30 p.

Veil, J.A., Daly, J.M., Johnson, N. 1999. EPA Speeds Regs for Offshore Synthetic-based Mud. Oil and Gas Journal, 97(37):78-85)

Whitney, J.W., Levinson, R.A., and van Alstine, D.R., 1985. Paleomagnetism of Early Tertiary Alaska Peninsula rocks and implications for docking of Peninsular Terrane, 60th Annual Meeting AAPG-SEPM-SEG Pacific Section Program and Abstracts, p. 32.

Waldron, H.H., 1961. Geologic reconnaissance of Frosty Peak volcano and vicinity, Alaska: U.S. Geological Survey Bulletin 1028-T, pp 677-708.

Wilson, F.H., 1980. Late Mesozoic and Cenozoic tectonics and the age of porphyry copper prospects, Chignik and Sutwik Island quadrangles, Alaska Peninsula: U.S. Geological Survey Open-file Report 80-543, 94 p., plates.

Wilson, F.H., Detterman, R.L., and Case, J.E., 1985. The Alaska Peninsula terrane; a definition: U.S. Geological Survey Open-File Report 85-450, 17 p.

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Figure 1

Ring Of Fire General Planning Area Map

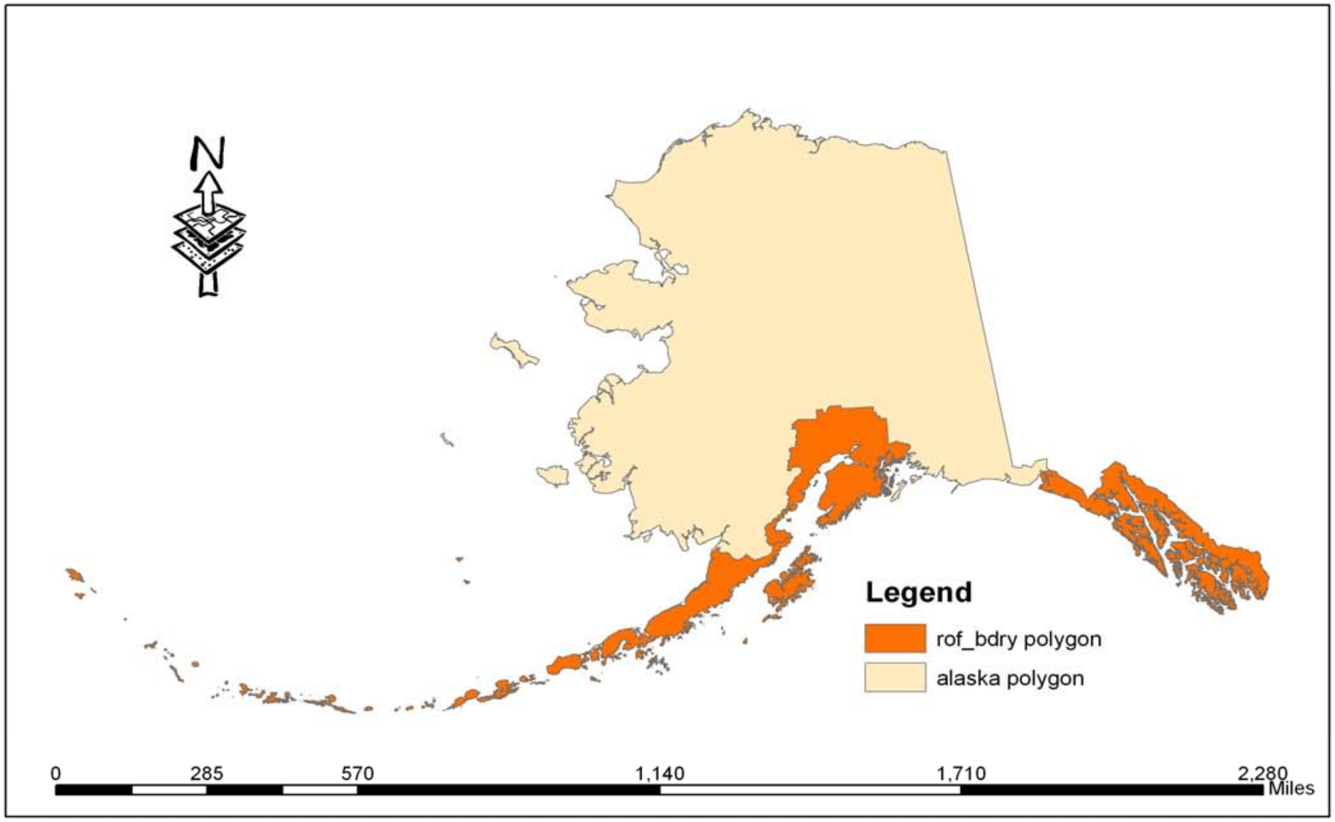

Figure 2

Pioneer Unit Location Map

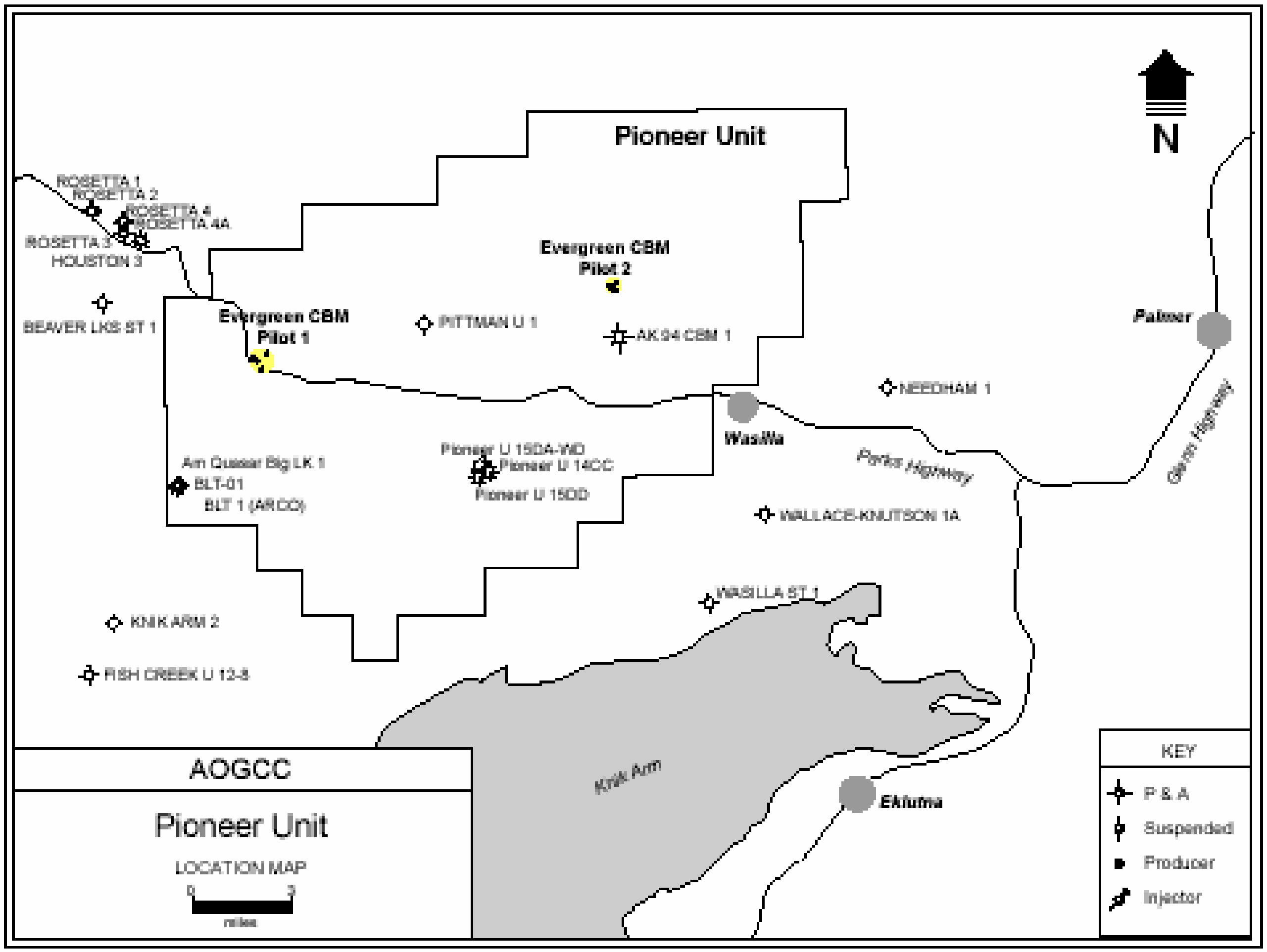

Figure 3

Historic and Projected Oil Production 1969 - 2022

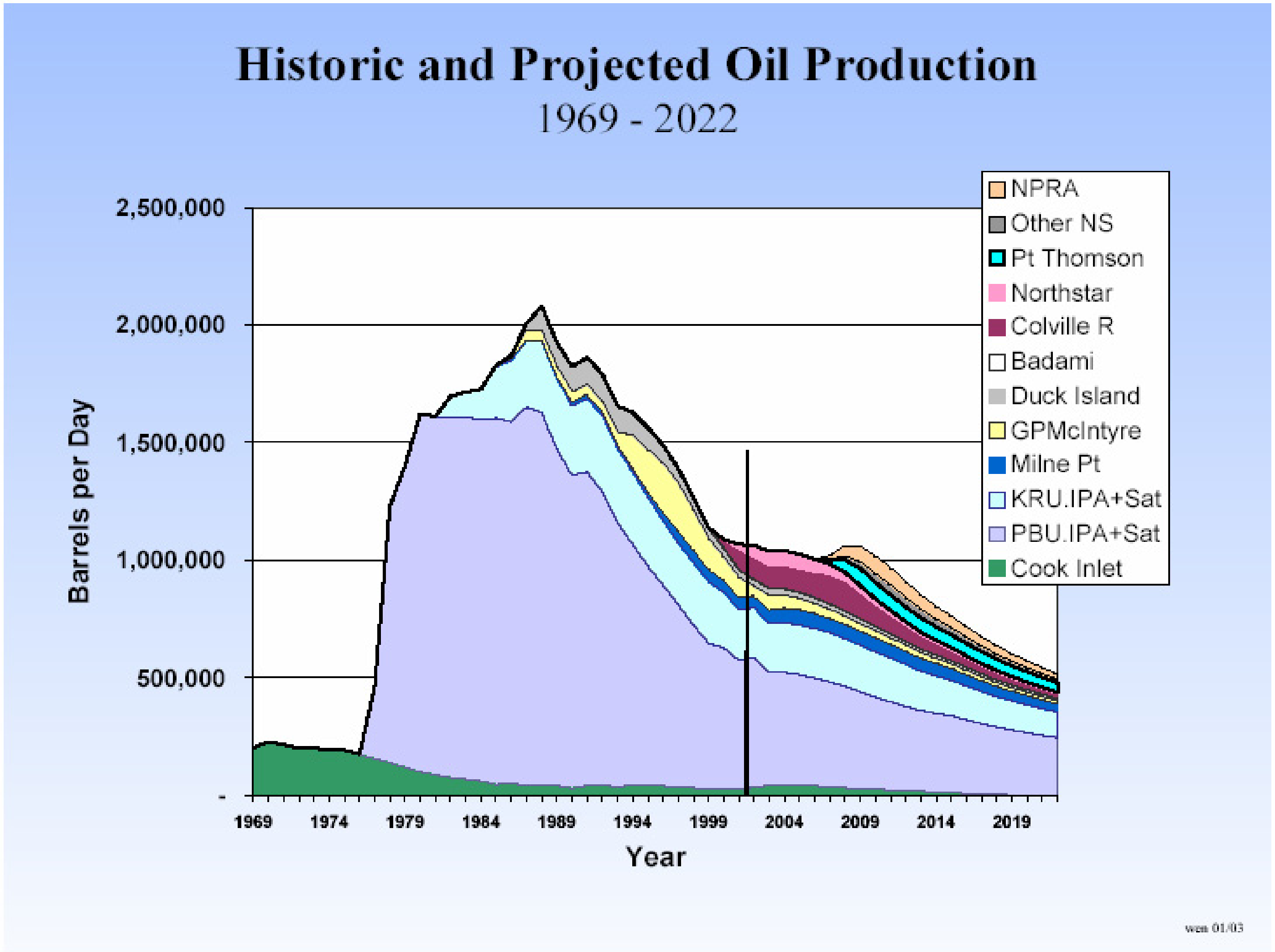

Figure 4
Alaska Peninsula Oil and Gas Area

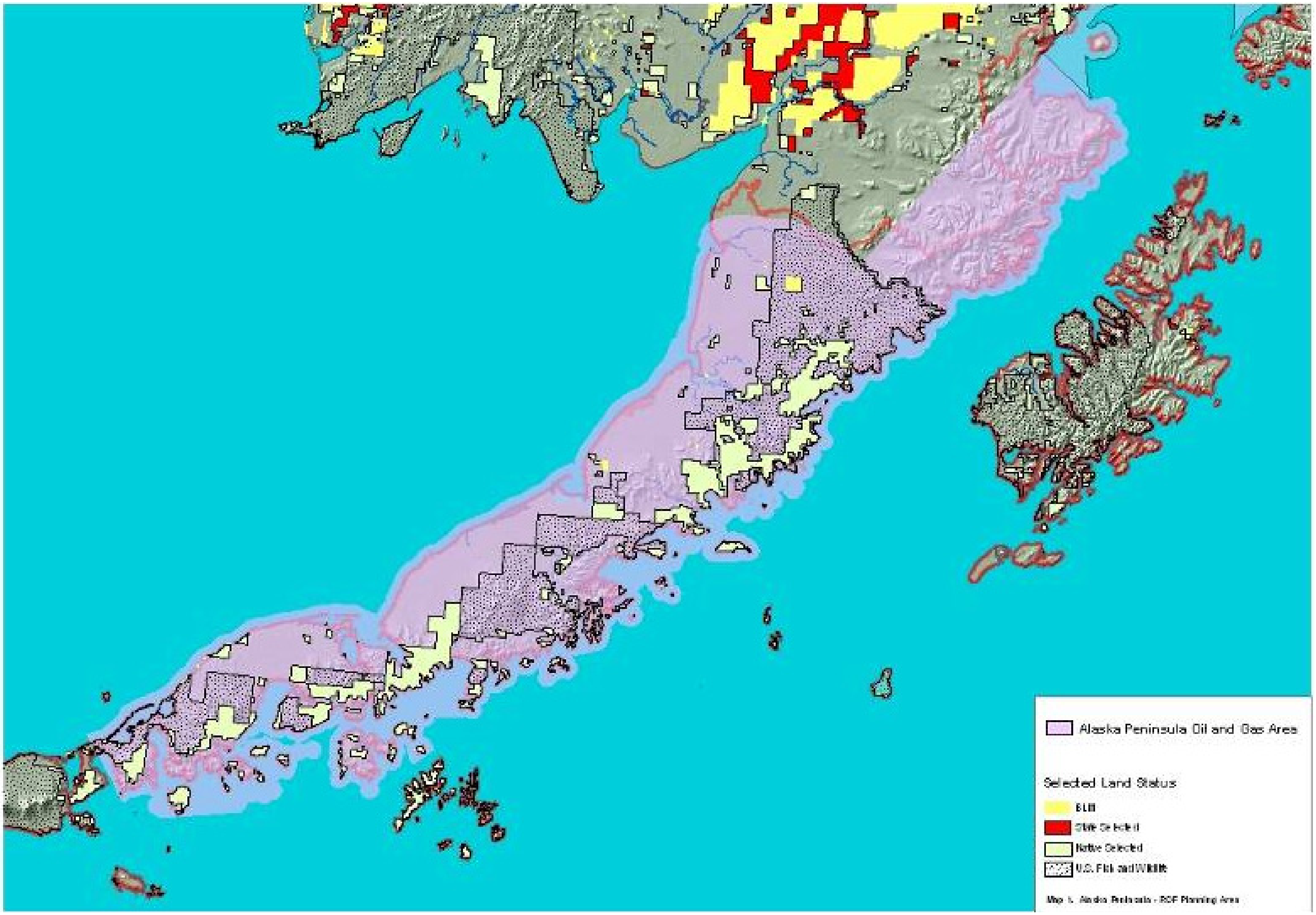

Figure 5
Cook Inlet Oil and Gas Basin

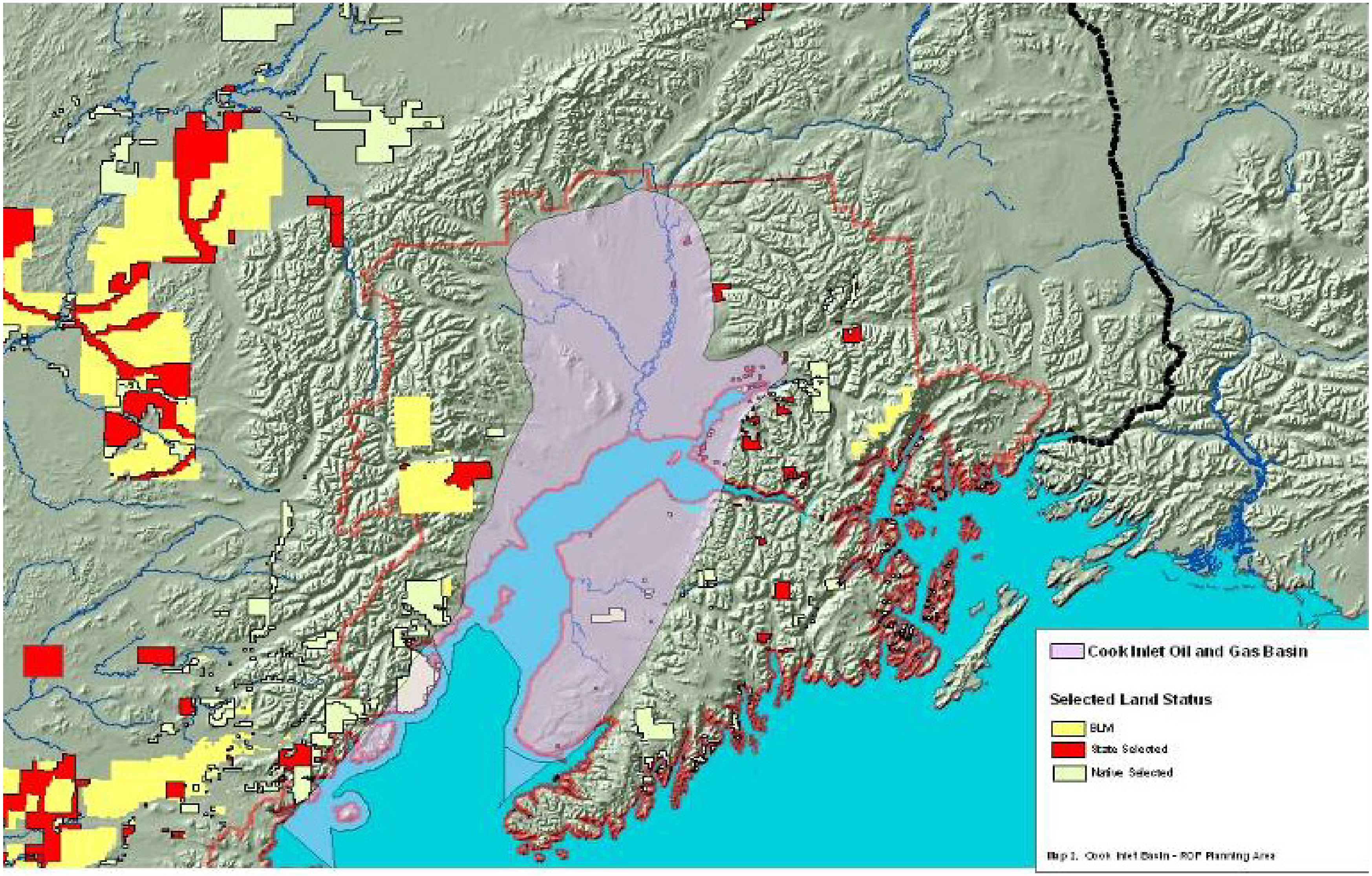

Figure 6
Yakutat Oil and Gas Area

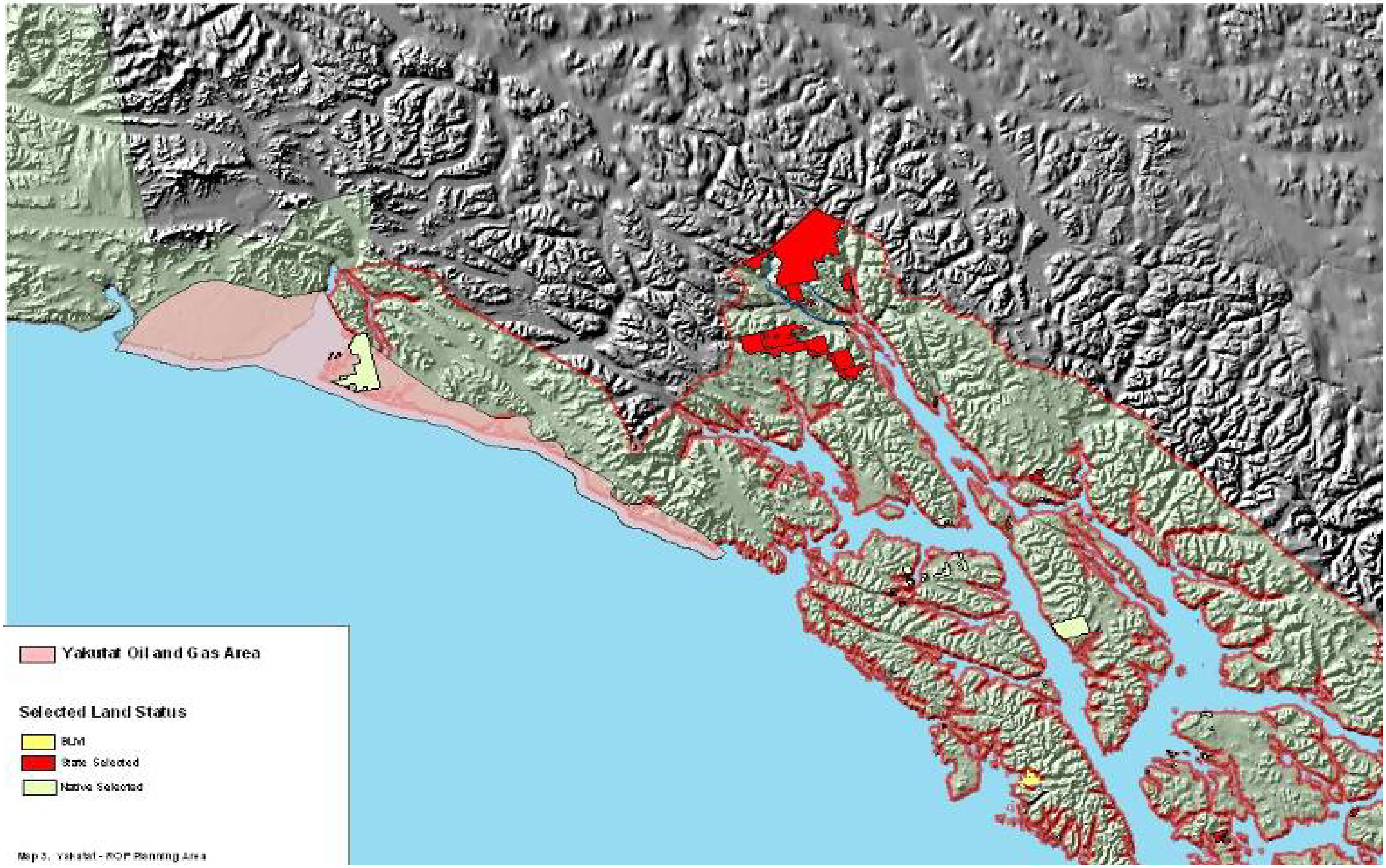

Figure 7
Areas of Potential Oil and Gas Development

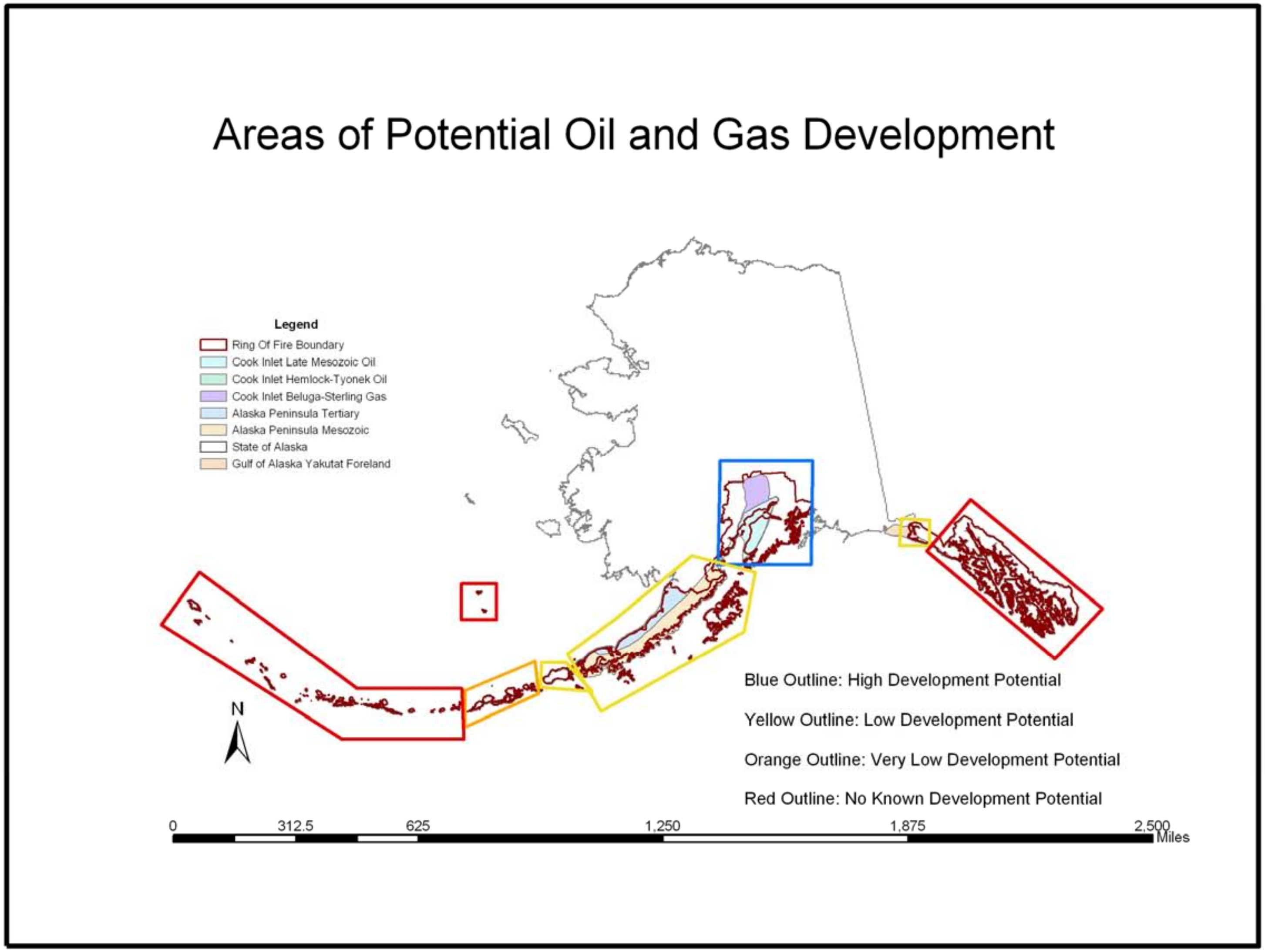

Figure 8
Areas of Potential Oil and Gas Occurrence

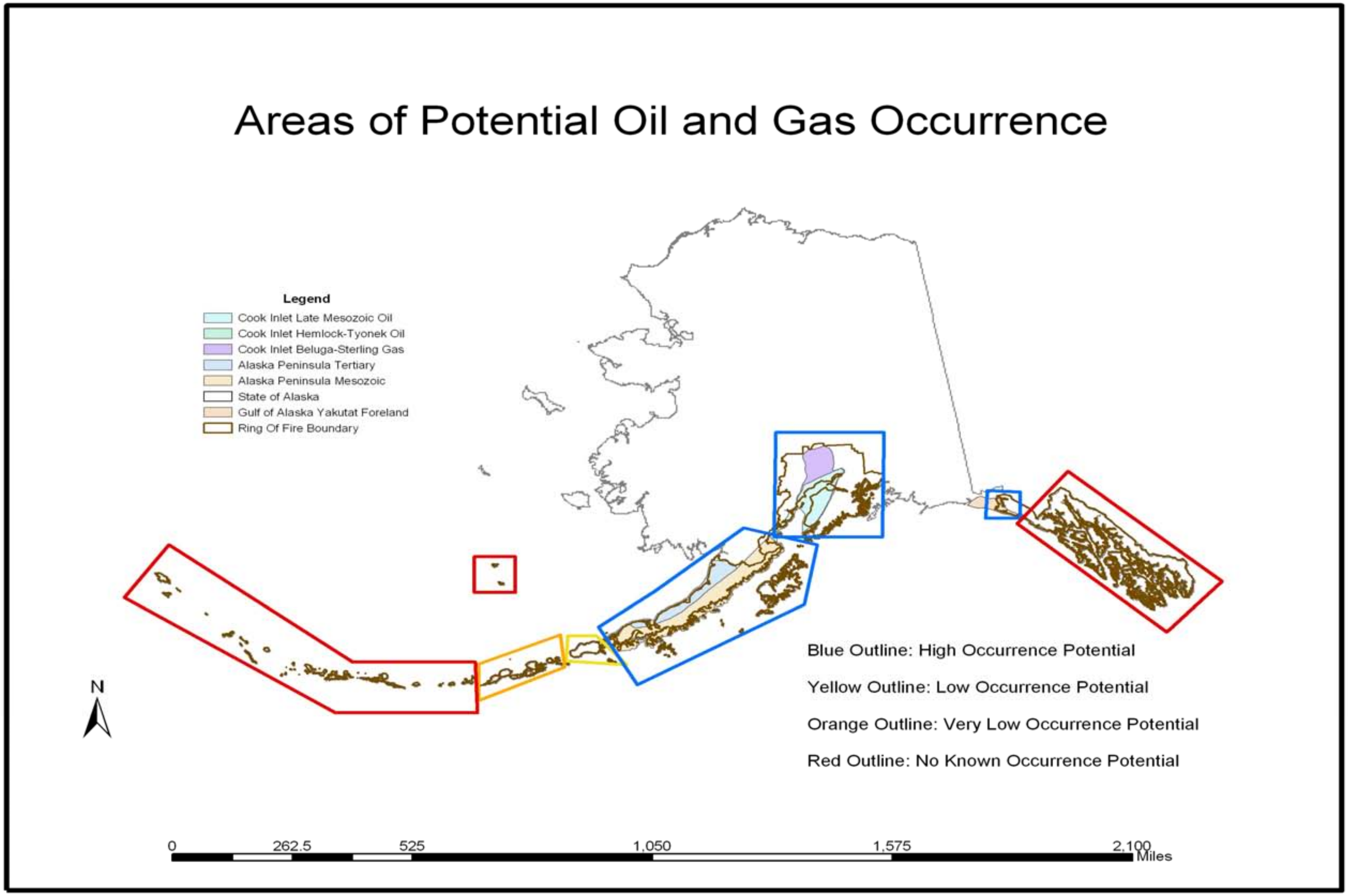

Table 1. Wells drilled for petroleum on the Alaska Peninsula (1903 to 1984).

	Well	Company	Year	T(S)	R(W)	sec	1/4 1/4	Depth	Formation	Results	Status
				Seward Meridian							
1	Pacific Oil #1	Pacific Oil & Commercial	1903	29	40	3	NW/4	1,421	Shelikof	Oil residue, shows, gas	P&A
2	Costello #1	J.H. Costello	1903	29	40	10	NW/4	728	Shelikof	Shows of oil & gas	P&A
3	Pacific Oil #2	Pacific Oil & Commercial	1904	29	40	3	SE/4	1,542	Shelikof	Shows of oil & gas	P&A
4	Costello #2	J.H. Costello	1904	29	40	10	SE/4	unknown	unknown	unknown	P&A
5	Lathrop #1	Standard Oil of Calif. Do.	1923	29	43	17	SE/4	500	Naknek	unknown	P&A
6	Finnegan #1	Tidewater Assoc.	1923	29	43	30	NE/4	560	Naknek	Trace of oil	P&A
7	McNally	Standard Oil of Calif.	1925	29	43	29	NW/4	510	Shelikof	Unknown	P&A
8	Lee #1	Standard Oil of Calif. Do.	1926	29	43	20	SW/4	5,034	Shelikof	Shows of oil & gas	P&A
9	Alaska #1	Tidewater Assoc.	1926	29	43	20	SW/4	3,033	Shelikof	Shows of oil & gas	P&A
10	Crammer #1	Standard Oil of Calif. Do.	1940	30	43	10	SE/4	7,596	unknown	Light oil in fractures, stain in Kialagvik Fm	P&A
11	Bear Creek #1	HumbleCShell	1959	29	41	36	NE/4	14,375	Kamishak	Oil stains in Kialagvik	P&A
12	Great Basins #1	General Petroleum Do.	1959	27	48	2	SW/4	11,080	Batholith	No oil shows are reported	P&A
13	Great Basins #2	General Petroleum Do.	1959	27	48	35	SE/4	8,865	Batholith	No oil shows are reported	P&A
14	Canoe Bay #1	Pure Oil	1963	54	78	8	NE/4	6,642	Hoodoo	No indication of oil generation	P&A
15	Wide Bay #1	Richfield Oil Co.	1963	33	44	5	NW/4	12,568	Kamishak	Oil stained sands in Kialagvik	P&A
16	Sandy River Fed #1	Gulf Oil Co.	1963	46	70	10	SE/4	13,068	Stepovak	Oil staining on sandstones at 10,000 ft	P&A
17	Ugashik #1	Great Basins Oil Co. .	1966	35	52	8	SE/4	9,476	Meshik	Oil staining noted at 10,000 ft.	P&A
18	Painter Creek #1	Cities Service So	1967	35	51	14	NW/4	7,912	Shelikof	Flowed gas. H20 cut in mud - Naknek Fm	P&A
19	David River # 1A	Pan American	1969	50	80	12	SE/4	13,769	Shelikof	Oil stained sands - Stepovak & Tolstoi	P&A
20	Hoodoo Lake #1	Pan American-Standard of Calif.	1970	50	76	21	NE/4	8,049	Stepovak	No indication of oil generation	P&A
21	Hoodoo Lake #2	Pan American-Standard of Calif.	1970	50	76	35	NE/4	11,243	Stepovak	Oil and gas shows in Stepovak and Tolstoi	P&A
22	Port Heiden #1	Gulf Oil Co.	1972	37	59	20	SE/4	15,015	Batholith	No indication of oil generation	P&A
23	Cathedral River #1	AMOCO Production	1974	51	83	29	SE/4	14,301	Unknown	Proprietary data	P&A
24	Big River #1	Phillips Petroleum Co.	1976	49	68	15	SW/4	11,371	Unknown	No known production	P&A
25	Koniag #1	Chevron Oil Co	1981	38	49	2	SW/4	10,907	Unknown	No known production	P&A
26	AMOCO Becherof St. 1	AMOCO	1984	28	48	10	NE/4	9,023	Unknown	No known production	P&A

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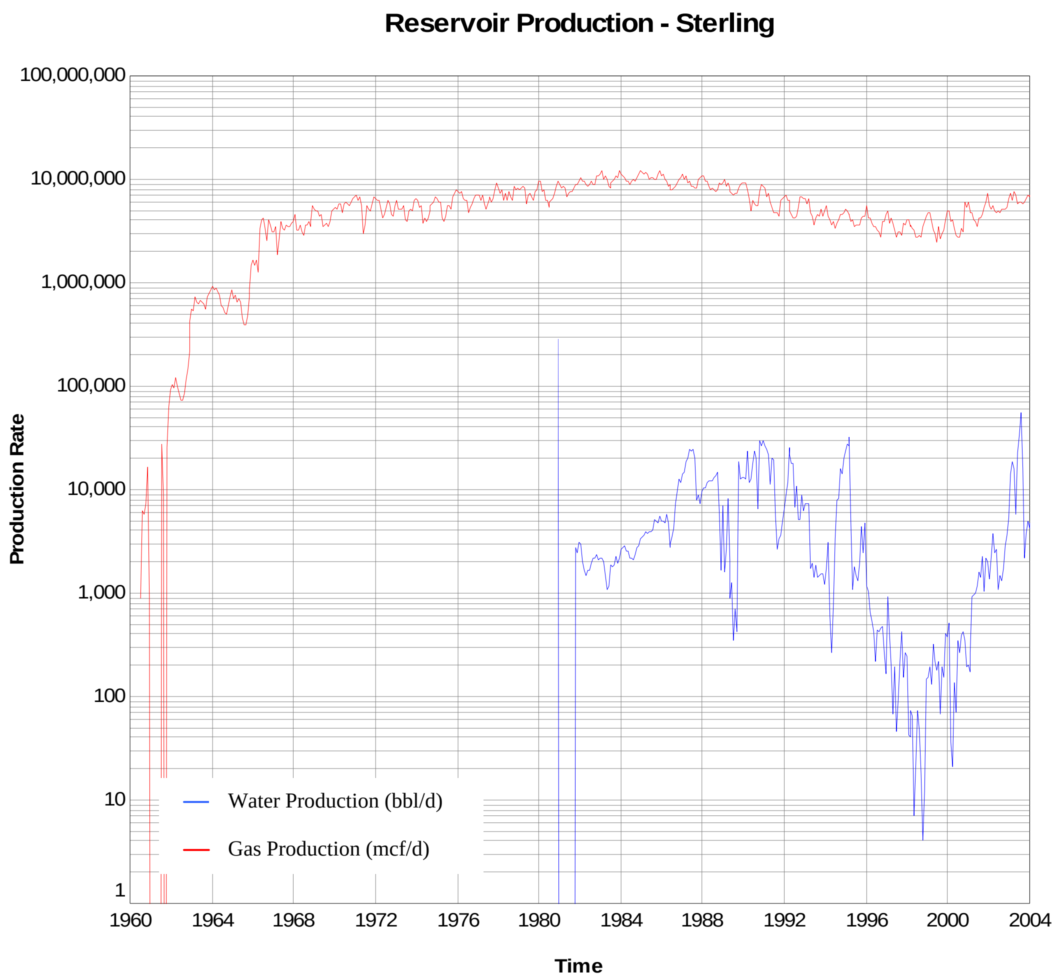
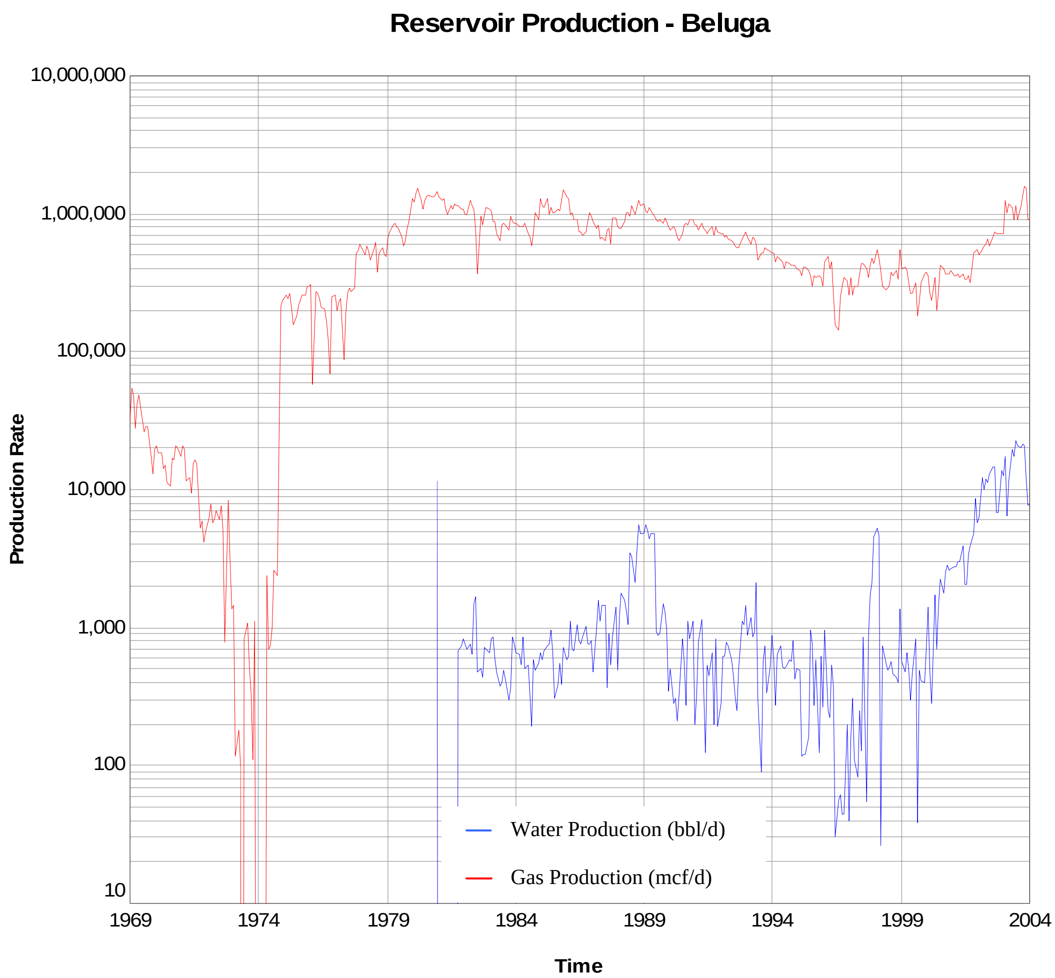
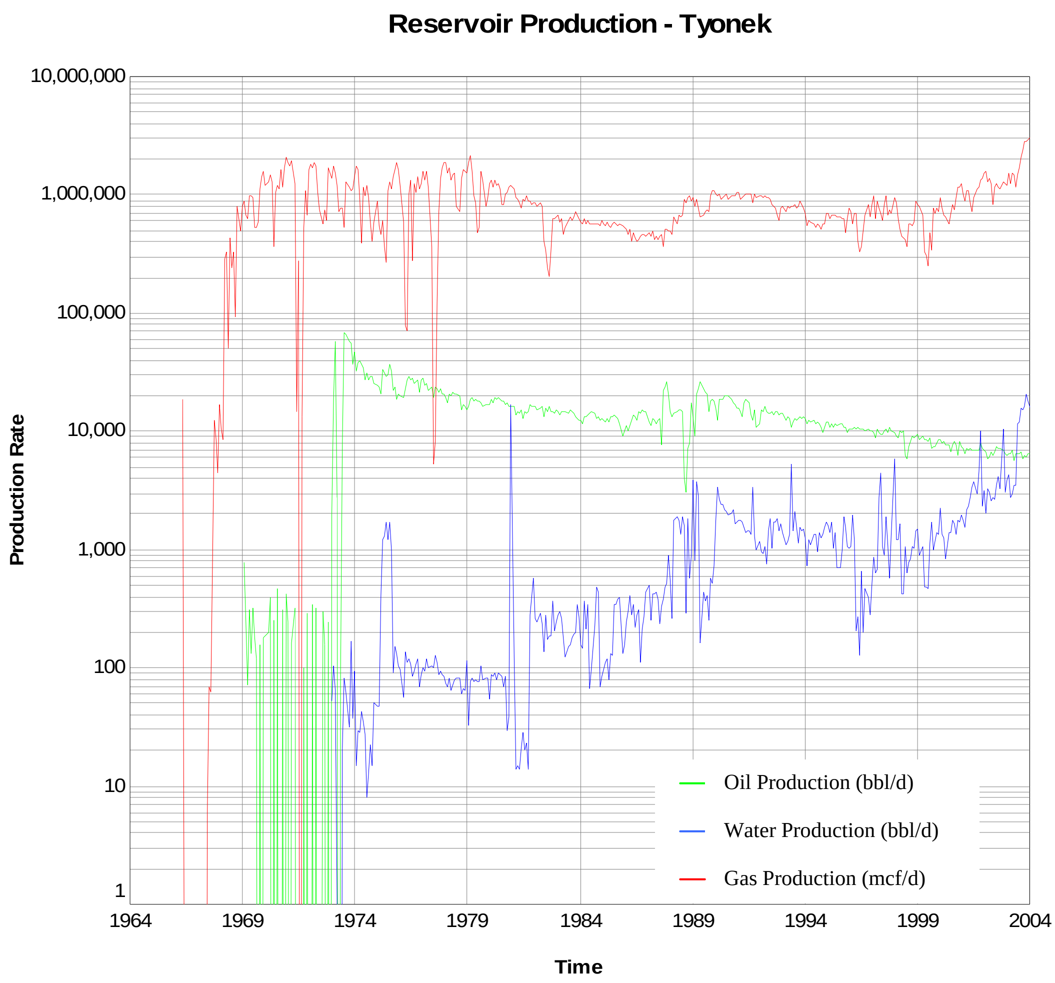
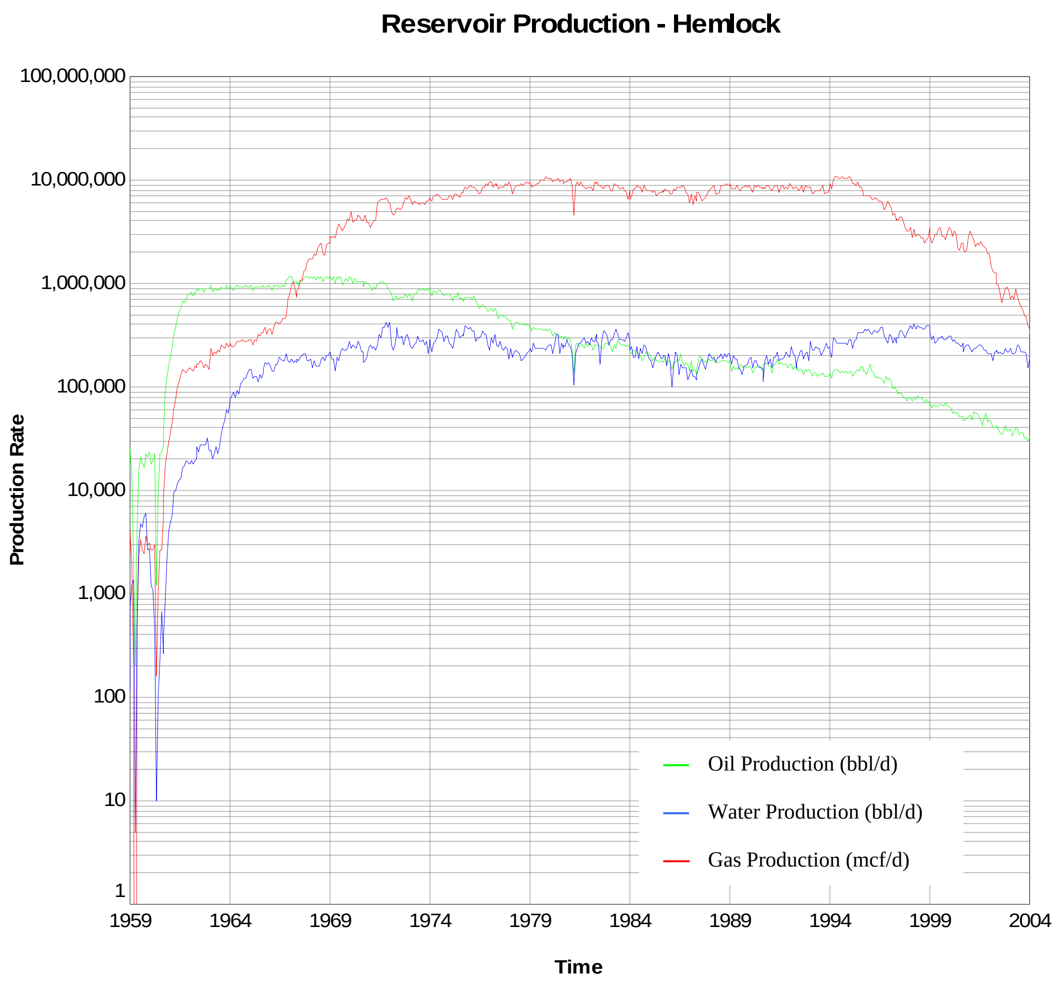
Appendix A

Production Graphs


Reservoir Production - Sterling
Production Rate
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
Time
Water Production (bbl/d)
Gas Production (mcf/d)


Reservoir Production - Beluga
10,000,000
1,000,000
100,000
10,000
1,000
100
10
Production Rate
1969
1974
1979
1984
1989
1994
1999
2004
Time
Water Production (bbl/d)
Gas Production (mcf/d)


Reservoir Production - Tyonek
Production Rate
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
1964
1969
1974
1979
1984
1989
1994
1999
2004
Time
Oil Production (bbl/d)
Water Production (bbl/d)
Gas Production (mcf/d)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Production Rate
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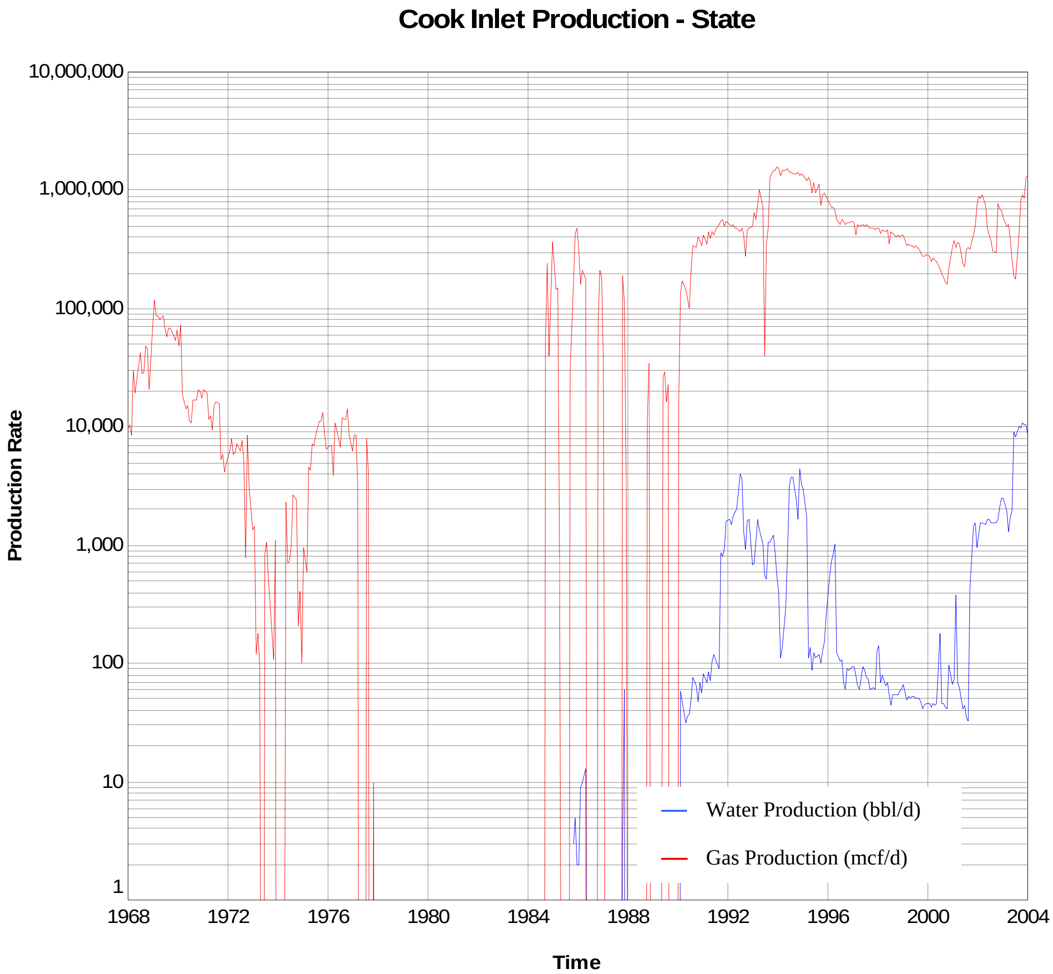
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
Time
Oil Production (bbl/d)
Water Production (bbl/d)
Gas Production (mcf/d)


Cook Inlet Production - State
Production Rate
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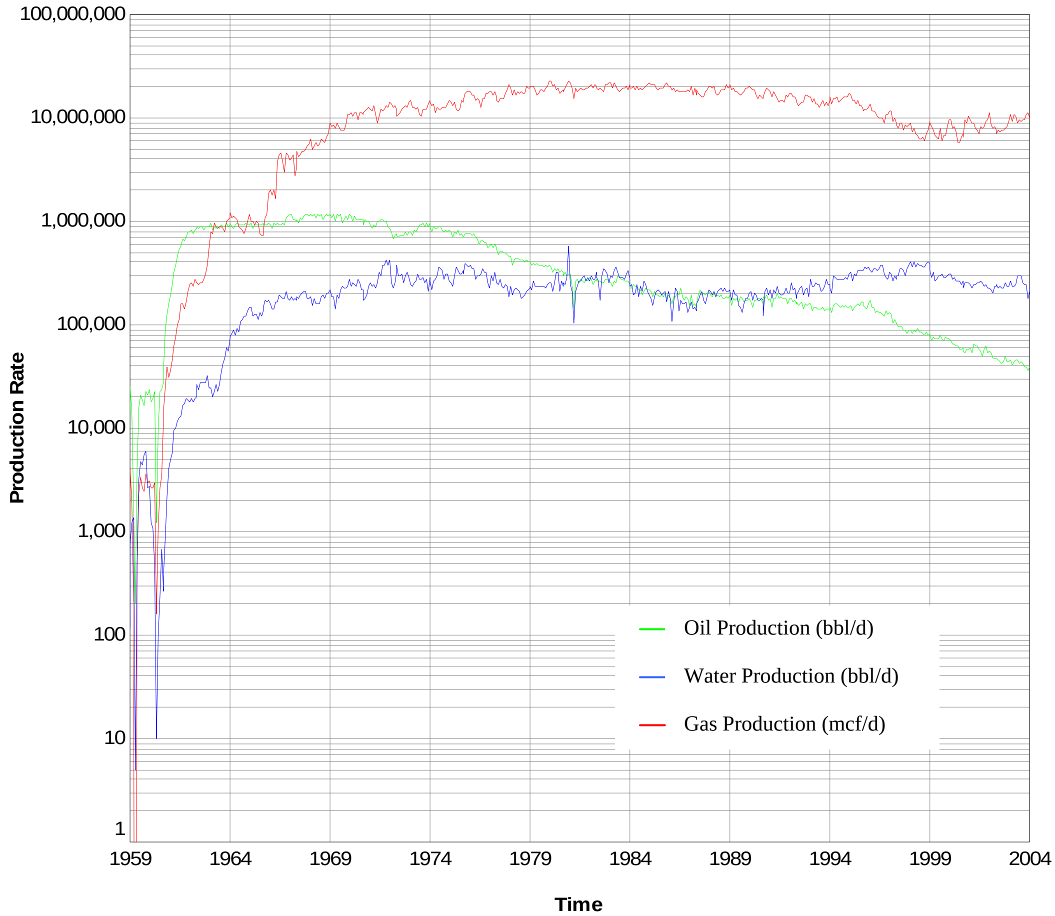
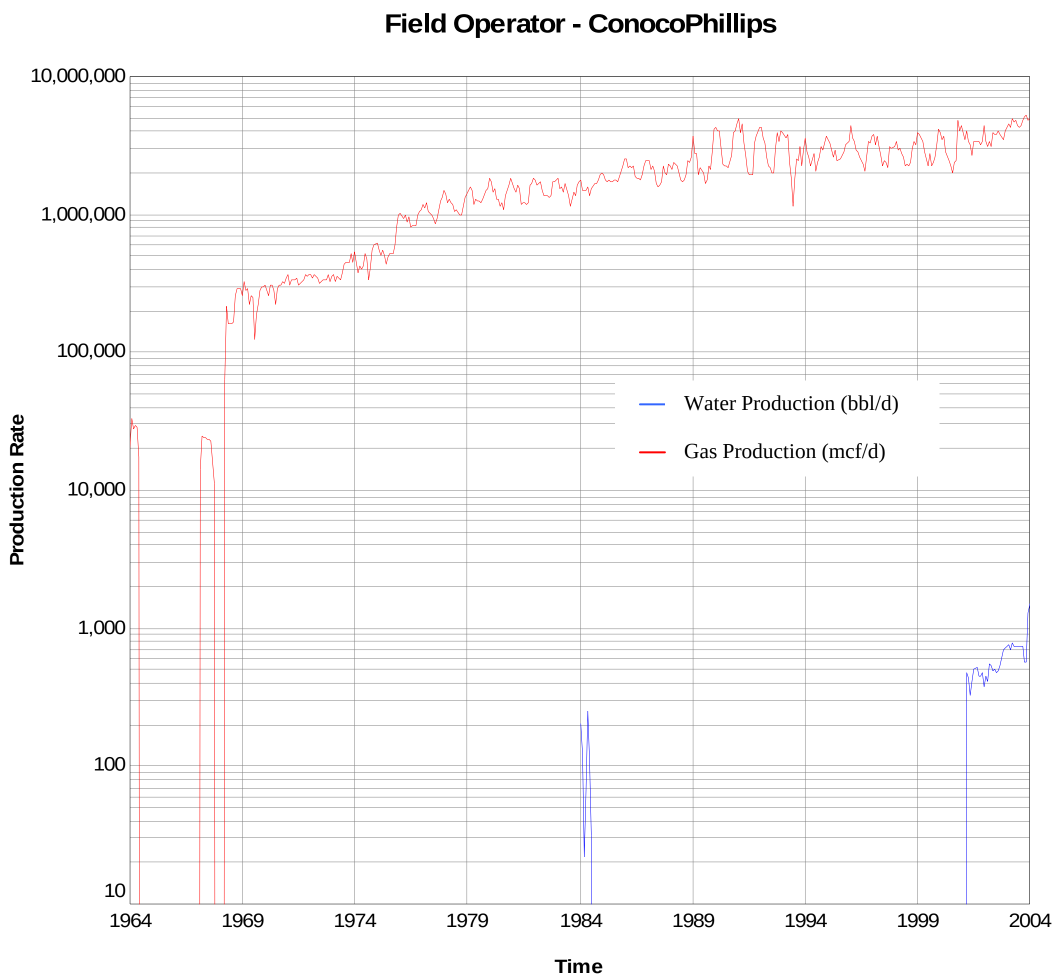
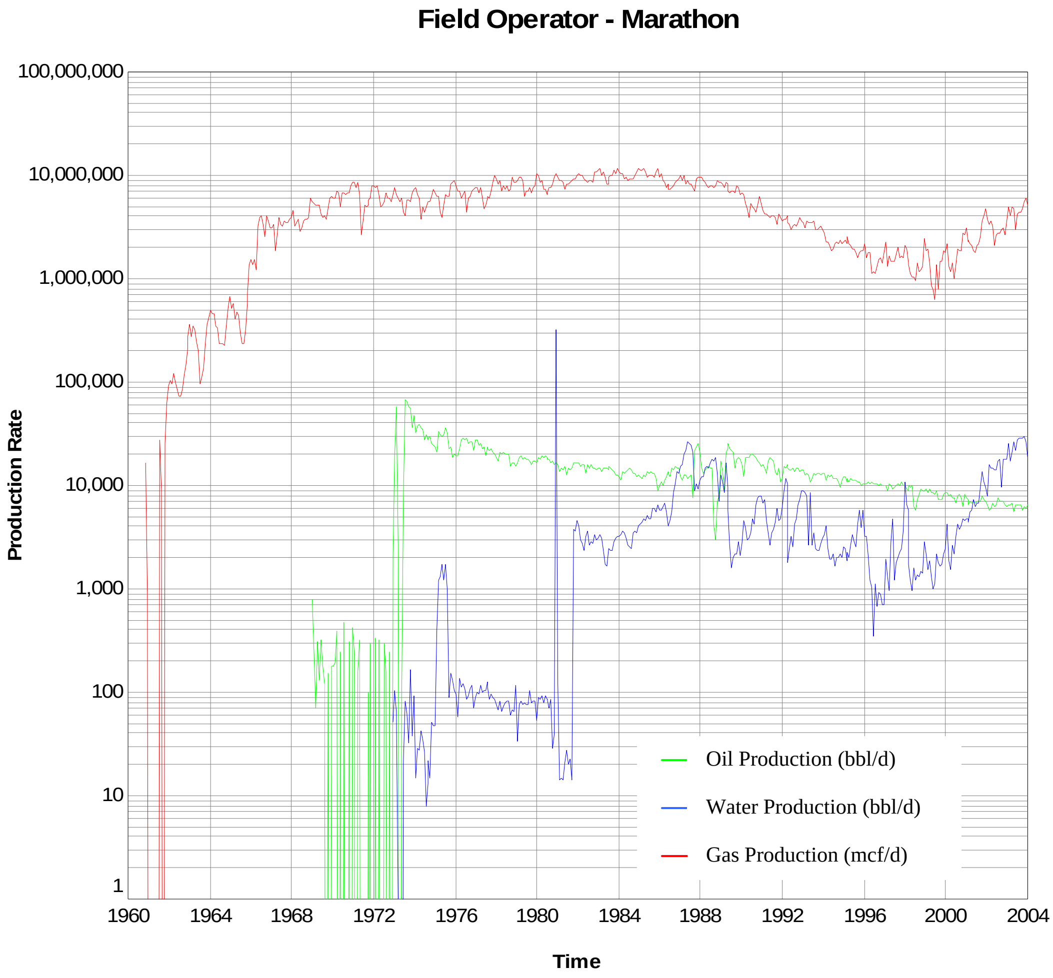
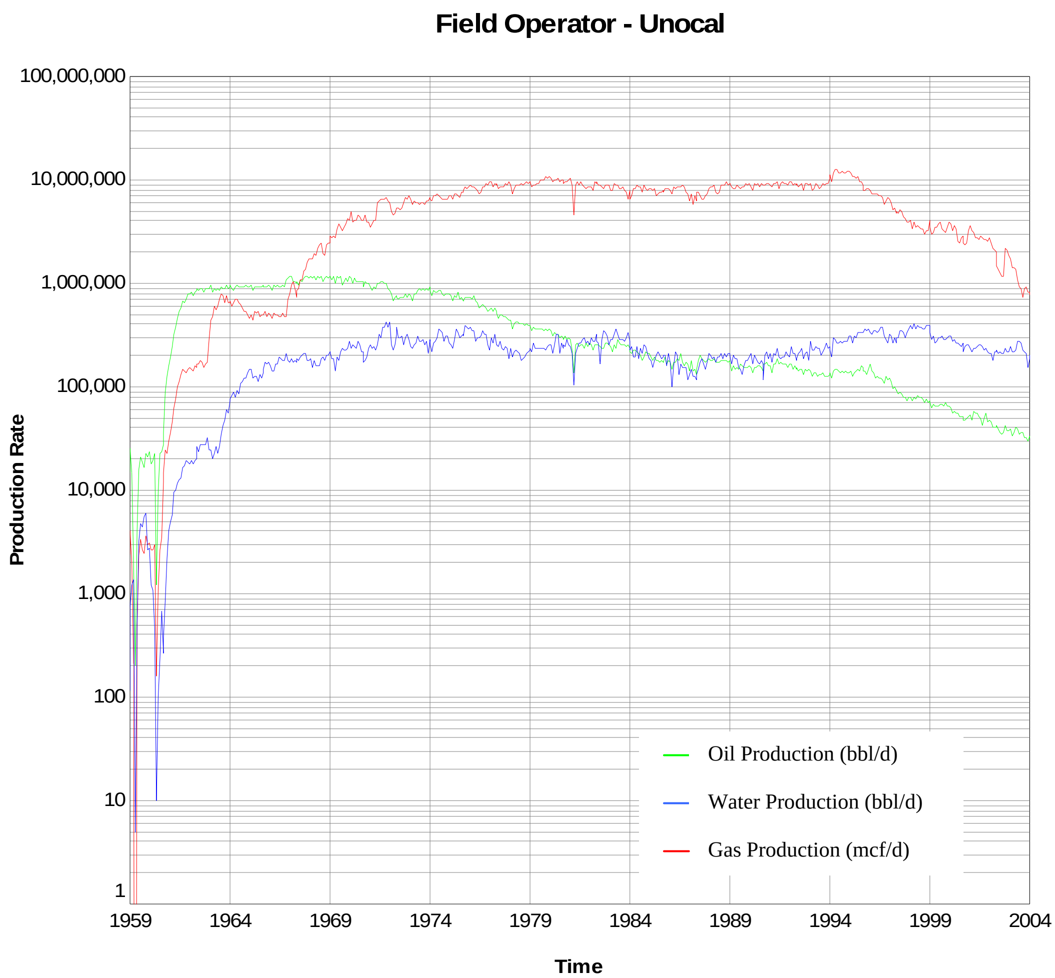
1,000,000
100,000
10,000
1,000
100
10
1
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
Time
Water Production (bbl/d)
Gas Production (mcf/d)

Cook Inlet Production - Federal




Field Operator - ConocoPhillips
10,000,000
1,000,000
100,000
10,000
1,000
100
10
Production Rate
1964
1969
1974
1979
1984
1989
1994
1999
2004
Time
Water Production (bbl/d)
Gas Production (mcf/d)


Field Operator - Marathon
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Production Rate
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
Time
Oil Production (bbl/d)
Water Production (bbl/d)
Gas Production (mcf/d)


Field Operator - Unocal
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
10
1
Production Rate
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
Time
Oil Production (bbl/d)
Water Production (bbl/d)
Gas Production (mcf/d)

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Attachment B

Reasonably Foreseeable Development Scenario For Locatable and Salable Minerals Ring of Fire Planning Area, Alaska

July 2006

REASONABLY FORESEEABLE DEVELOPMENT SCENARIO
FOR LOCATABLE AND SALABLE MINERALS
RING OF FIRE PLANNING AREA, ALASKA

Prepared for

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

ANCHORAGE FIELD OFFICE

Prepared by

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT

ALASKA STATE OFFICE

DIVISION OF ENERGY AND SOLID MATERIALS

JULY 2006

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ACRONYMS AND ABBREVIATIONS

ADNR	Alaska Department of Natural Resources
AEIDC	Arctic Environmental Information and Data Center
AFO	Anchorage Field Office
AMIS	Alaska Mineral Information System
APMA	Alaska Placer Mining Application
ARDF	Alaska Resource Data Files
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
CNF	Chugach National Forest
DGGS	Alaska Division of Geological and Geophysical Surveys
FEIS	Final Environmental Impact Statement
FLPMA	Federal Land Policy and Management Act
KMDA	Known Mineral Deposit Area
kW	kilowatt
MAS/MILS	Mineral Availability System/Mineral Industry Location System
NEPA	National Environmental Policy Act
PGE	platinum group elements
PRMP	Proposed Resource Management Plan
PWS	Prince William Sound
RDI	Resource Data, Inc.
RFD	Reasonably Foreseeable Development
st	short ton
stpd	short ton per day
TNF	Tongass National Forest
URS	URS Corporation
U.S.	United States
USBOM	U.S. Bureau of Mines
USGS	U.S. Geological Survey

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EXECUTIVE SUMMARY

The Anchorage Field Office (AFO) of the Bureau of Land Management (BLM) has prepared a Proposed Resource Management Plan (PRMP)/Final Environmental Impact Statement (FEIS) for the Ring of Fire planning area to provide a comprehensive framework for managing and allocating uses of the public lands and resources within the Anchorage District. This planning process meets the requirements of the National Environmental Policy Act (NEPA) through a detailed description of the alternatives and environmental consequences resulting from each alternative. The Federal Land Policy and Management Act of 1976 (FLPMA) requires the Secretary of the Interior, with public involvement, to develop, maintain, and when appropriate, revise land use plans that provide tracts or areas for the use of the public lands.

The Ring of Fire planning area encompasses an area from the Aleutian Islands at the southwestern tip of Alaska, through the Alaska Peninsula, parts of southcentral Alaska, through the southeast panhandle. The planning area is divided into four geographic regions: Alaska Peninsula/Aleutian Chain region, Kodiak region, southcentral region, and southeast region.

Reasonably Foreseeable Development (RFD) scenarios provide a mechanism to analyze the effects that discretionary planning decisions have on mineral development based upon four alternatives. This RFD scenario is used to predict the type, location, and manner of potential disturbance due locatable minerals extraction in the planning area over the next 15 years. This report has been formulated to project and predict development regardless of specific land management authority (federal, State, Native, or private), but concentrates on the high mineral potential areas located on unencumbered BLM lands and State- and Native-selected lands.

A range of four alternatives was developed during the Ring of Fire PRMP/FEIS process. These include Alternative A – No Action (Current Management), Alternative B – Resource Development, Alternative C – Resource Conservation, and Alternative D – Proposed Action. Due to the diminutive amount of BLM-managed lands within the planning area, the level of disturbance from reasonably foreseeable locatable mineral activity would be minimal. If the maximum amount of activity is allowed (Alternative B – Resource Development), an estimated total of 59 acres could potentially be disturbed in the Ring of Fire planning area. If the least amount of activity is allowed (Alternative C – Resource Conservation), an estimated total of 5 acres could potentially be disturbed on existing valid operation in the Ring of Fire planning area. If reasonable accommodations are given to all parties, (Alternative D – Proposed Action), an estimated maximum total of 59 acres could potentially be disturbed in the Ring of Fire planning area. However, due to its sensitive nature, the Neacola Mountains-Blockade Glacier area could remain closed to mineral entry and thus diminish the disturbed acreage estimate.

1.0 INTRODUCTION

The Anchorage Field Office (AFO) of the Bureau of Land Management (BLM) has prepared a Proposed Resource Management Plan (PRMP)/Final Environmental Impact Statement (FEIS) in the Ring of Fire planning area to provide a comprehensive framework for managing and allocating uses of the public lands and resources within the Anchorage District. This planning process will meet the requirements of the National Environmental Policy Act (NEPA) through a detailed description of the alternatives and environmental consequences resulting from each alternative. The Federal Land Policy and Management Act of 1976 (FLPMA), as amended, provides the authority for the BLM land use planning on public lands. In particular, Section 202 (a) requires the Secretary of the Interior, with public involvement, to develop, maintain, and when appropriate, revise land use plans that provide by tracts or areas for the use of the public lands. Implementing regulations are contained in 43 Code of Federal Regulations (CFR) 1610. BLM Manual, 1601 Land Use Planning, and a handbook (H-1601-1 Land Use Planning Handbook), provide procedures and guidance for the planning process.

The Ring of Fire planning area encompasses an area some 2,500 miles long, from the Aleutian Islands at the southwestern tip of Alaska, through the Alaska Peninsula, parts of southcentral Alaska, through the southeast panhandle. The planning area is divided into four geographic regions: (1) Alaska Peninsula/Aleutian Chain region, (2) Kodiak region, (3) southcentral region, and (4) southeast region. The southcentral region includes the Cook Inlet area, Matanuska-Susitna Valley, and Kenai Peninsula, but excludes eastern Prince William Sound (PWS) and the Wrangell Mountains to the east. The southeast region extends from Yakutat Bay to the southeastern tip of Alaska.

This Reasonably Foreseeable Development (RFD) scenario: 1) provides a mechanism to analyze the effects that discretionary planning decisions have on mineral development, and 2) summarizes basic information used in developing the various alternatives analyzed in the NEPA document. By incorporating available geologic and economic information, as well as utilizing federal and State mineral assessment reports, this RFD scenario is used to predict the type, location, and manner of potential locatable mineral extraction in the Ring of Fire planning area over the next 15 years. RFD scenario’s have been formulated to project and predict development regardless of specific land management authority, federal, State, Native, or private; but concentrates on the high mineral potential areas located on unencumbered BLM land and State- and Native-selected lands. The following sections present what has been identified about the geology, known mineral occurrences, and unknown potential of the Ring of Fire planning area.

2.0 DESCRIPTION OF GEOLOGY

2.1.1 Mineral Terranes

The Ring of Fire planning area is underlain by 13 mineral terrane units whose geologic settings are considered highly favorable for the existence of metallic mineral resources (Arctic Environmental Information and Data Center [AEIDC] 1982, Resource Data, Inc. [RDI] *et al.* 1995). The geologic nature of each terrane will determine specific commodities and mineral deposit types. Unmapped areas are generally evaluated as having poor to only moderate mineral potential. Mineral terranes located within each region are discussed below and listed in Table 1 and shown in Figures 1 through 3.

Table 1. Mineral Terranes Identified in the Ring of Fire Planning Area

Map unit	Name	Description	Favorable deposits
IGA	Alkalic granitic rocks	Syenite, locally including peralkaline granite and monzonite	Uranium, rare earth elements, and molybdenum
IGF	Felsic granitic rocks	Granite and quartz monzonite	Tin, tungsten, molybdenum, uranium, and thorium
IGI	Intermediate granitic rocks	Granodiorite and quartz diorite	Copper, gold, and molybdenum
IGU	Undivided granitic rocks	Granite	Uranium, thorium, rare earth elements, tin, tungsten, molybdenum, copper, and gold
IMA	Mafic intrusive rocks	Gabbro, locally including mafic-rich intermediate rocks including mafic monzonite and diorite	Copper and nickel with byproduct platinum and cobalt
IUM	Ultramafic rocks	Peridotite and dunite	Chromium, nickel, and platinum group metals with byproduct cobalt
SCB	Continental sedimentary rocks	Coal-bearing sandstone, shale, and conglomerate	Coal and uranium with byproduct vanadium
SGS	Graywacke and shale	Interbedded with minor volcanic rocks	Gold or a variety of metals
VFI	Intermediate volcanic rocks	Trachyandesite and andesite	Uranium and thorium
VFU	Felsic volcanic rocks	Undivided hyolite and quartz latite	Copper, lead, and zinc with byproduct silver and gold
VMU	Mafic volcanic rocks	Undivided primarily basalt	Copper and zinc with byproduct silver and gold
VSF	Sedimentary and felsic volcanic rocks	Undivided rhyolite, quartz latite, and associated sediments	Copper and zinc with byproduct silver and gold
VSM	Sedimentary and mafic volcanic rocks	Undivided basalt and associated sediments	Copper and zinc with byproduct silver and gold

Alaska Peninsula/Aleutian Chain Region: Felsic granitic rocks; favorable for tin, tungsten, molybdenum, uranium, and thorium deposits. Intermediate granitic rocks; favorable for copper, gold, and molybdenum deposits. Coal-bearing sedimentary rocks; favorable for coal and uranium with byproduct vanadium deposits. Felsic and intermediate volcanic rocks; favorable for epithermal gold, silver, and mercury deposits. Undivided mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold. Undivided sedimentary and felsic volcanic rocks; favorable for copper, lead, and zinc deposits with byproducts of silver and gold. Undivided sedimentary and mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold (Figure 1).

Kodiak Region: Felsic granitic rocks; favorable for tin, tungsten, molybdenum, uranium, and thorium deposits. Intermediate granitic rocks; favorable for copper, gold, and molybdenum deposits. Ultramafic rocks; favorable for chromium, nickel, and platinum group metal deposits with byproduct of cobalt. Graywacke and shale; favorable for gold deposits or a variety of metals. Undivided sedimentary and mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold (Figure 1).

Southcentral Region: Felsic granitic rocks; favorable for tin, tungsten, molybdenum, uranium, and thorium deposits. Intermediate granitic rocks; favorable for copper, gold, and molybdenum deposits. Undivided granitic rocks: favorable for uranium, thorium, rare earths, tin, tungsten, molybdenum, copper, and gold deposits. Mafic intrusive rocks; favorable for copper and nickel deposits with byproducts of platinum and cobalt. Ultramafic rocks; favorable for chromium, nickel, and platinum group metal deposits with byproduct of cobalt. Coal-bearing sedimentary rocks; favorable for coal and uranium deposits with byproduct of vanadium. Interbedded graywacke and shale with minor volcanic rocks; favorable for gold or a variety of metal deposits. Felsic and intermediate volcanic rocks; favorable for epithermal gold, silver, and mercury deposits. Undivided mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold. Undivided sedimentary and mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold (Figure 2).

Southeast Region: Alkalic granitic rocks; favorable for uranium and rare earths deposits. Felsic granitic rocks; favorable for tin, tungsten, molybdenum, uranium, and thorium deposits. Intermediate granitic rocks; favorable for copper, gold, and molybdenum deposits. Undivided granitic rocks; favorable for uranium, thorium, rare earths, tin, tungsten, molybdenum, copper, and gold deposits. Mafic intrusive rocks; favorable for copper and nickel deposits with byproducts of platinum and cobalt. Ultramafic rocks; favorable for chromium, nickel, and platinum group metal deposits with byproduct of cobalt. Coal-bearing sedimentary rocks; favorable for coal and uranium deposits with byproduct of vanadium. Interbedded graywacke and shale with minor volcanic rocks; favorable for gold or a variety of metal deposits. Undivided felsic volcanic rocks; favorable for copper, lead, and zinc deposits with byproducts of silver and gold. Undivided mafic volcanic rocks favorable for copper and zinc deposits with byproducts of silver and gold. Undivided sedimentary and felsic volcanic rocks; favorable for copper, lead, and zinc deposits with byproducts of silver and gold. Undivided sedimentary and mafic volcanic rocks; favorable for copper and zinc deposits with byproducts of silver and gold (Figure 3).

2.2 Known Mineral Deposit Areas

Known Mineral Deposit Areas (KMDAs) are described as a management tool for determining the likelihood of future discoveries in a particular area. They are based on a high concentration of historic mines and prospects, mineral occurrences in the Mineral Availability System/Mineral Industry Location System (MAS/MILS) database, and favorable geologic trends determined by mineral terrane mapping and have either been identified during mineral assessment studies or shown on the Mineral Terranes of Alaska map (Maas et al 1995; RDI *et al.* 1995). Bittenbender *et al.* (1999) and Still *et al.* (2002) define KMDAs as having a high concentration of mineral occurrences of a single type, which suggests an increased likelihood that the rocks host significant mineral deposits compared to other areas. The most recent version of KMDAs electronically available (RDI *et al.* 1995) is depicted on Figures 1 through 3. In some areas of the Ring of Fire planning area, more recent BLM or United States (U.S.) Geological Survey

(USGS) have resulted in revisions of KMDA boundaries investigations (e.g., Bittenbender *et al.* 1999; Nelson and Miller 2000; Still *et al.* 2002).

Alaska Peninsula/Aleutian Chain Region: No KMDAs have been identified in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No KMDAs have been identified in the Kodiak region.

Southcentral Region: No KMDAs have been identified in the southcentral region.

Southeast Region: KMDAs were established in the southeast region during development of the Tongass National Forest (TNF) Land Management Plan in 1991, and during the mid-1990s for the rest of the Ring of Fire planning area by the U.S. Bureau of Mines (USBOM) (RDI *et al.* 1995).

2.3 High Mineral Occurrence Potential Areas

High, medium, and low mineral potential areas within the Ring of Fire planning area have been identified in the Mineral Occurrence and Development Report written by URS Corporation (URS) (2004) and are shown on the locatable mineral potential maps (Figures 1 through 3). The following section is based upon those findings.

Alaska Peninsula/Aleutian Chain Region: Seven small areas with high mineral potential have been identified in the Alaska Peninsula/Aleutian Chain region. The sites include: Mount Chiginak area; northern Chignuk Bay-Black Peak area; the southern part of Unga Island; the Mount Dana area; two locations on Unalaska Island at the northwest and southeastern areas; and the central Umnak Island between Inanudak Bay and Thumb Point (Figure 4).

Kodiak Region: Three small areas with high mineral potential have been identified on Kodiak Island and two small areas on the Trinity Islands. The sites on Kodiak Island include: just north of Low Cape on the west end of the island; the area along Sevenmile Beach; east of Rocky Point; on the northwest end of the island; and the area between the head of Uganik Passage and Terror Bay on the northwest end of the island. The sites on the Trinity Islands include the western end of Tugidak Island and the southwestern edge of Sitkinak Island (Figure 4).

Southcentral Region: Thirty-four areas with high mineral potential have been identified in the southcentral region. The sites include: the headwaters of Crevice Creek; the north side of Bruin Bay; Mt. Spurr; the Tordrillo Mountains; the Camp Creek area; the Peters Creek and Cache Creek area; the Talkeetna Mountains; the Willow Creek and Chickaloon areas; the Girdwood area; Resurrection Creek to Cooper Landing area; Moose Pass to Seward area; Knight Island; and several sites in the western PWS (Figure 5).

Southeast Region: Thirty-three areas with high mineral potential have been identified in the southeast region. The sites include: two areas near Yakutat along Monti Bay and the Black sand Spit areas; the Minnesota Ridge in the Muir Inlet area; two areas on Mt. Seltat; four areas along Lynn Canal, three on the east side and on the west side; the Juneau area, two sites on the west side of Taku Inlet, the northern part of Admiralty Island; six sites scattered along Baranof Island; on the southeastern side of Kupreanof Island; the northwest and southeast sides of Cleveland Peninsula; five sites on the eastern to southern end of Prince of Wales Island; and the southcentral part of Duke Island (Figure 6).

3.0 HISTORICAL EXPLORATION ACTIVITY

Historical exploration activity is discussed here to describe the extent of current mineral industry activity within the entire Ring of Fire planning area. This discussion creates a baseline of understanding as to which target areas the mineral industry is interested and to what extent their activity is occurring. Information for this section comes from numerous sources including the BLM and State mining claim databases, Alaska Division of Geological and Geophysical Surveys (DGGS) 2003 *Mineral Industry Activity Report* (Szumagala *et al.* 2004), and URS's Draft *Mineral Occurrence Potential Report* (2004).

3.1.1 Mineral Claim Staking

Mining claims have been staked throughout the Ring of Fire planning area. Extensive claim staking has historically occurred on Unga Island, the Petersville-Cache Creek, Collinsville, Hatcher Pass, Crow Creek, Hope/Resurrection Creek, Haines-Skagway, Juneau-Admiralty Island, Chichagof-Baranof Island, Stikine, Ketchikan-Hyder, and Duke Island areas. The following discussion covers the entire area, and then defines those mining claims staked on BLM unencumbered, State- or Native-selected lands.

Alaska Peninsula/Aleutian Chain Region: The only active claims in the Alaska Peninsula/Aleutian Chain region are State claims on Unga Island. These claims are not located on BLM unencumbered, State- or Native-selected lands.

Kodiak Region: There are no active federal or State mining claims on BLM unencumbered, State- or Native-selected lands on Kodiak Island.

Southcentral Region: Numerous active federal and State mining claims are located in the southcentral region. No active mining claims are located on BLM unencumbered lands. A dozen or so federal claims are located on state land in the Petersville-Cache Creek, Collinsville, and Hatcher Pass areas, and have federal subsurface estate. These claims were located prior to State selection, and the federal government retains the subsurface estate as long as these claims remain active. Very few active mining claims are actually located on State- and Native-selected lands. Those active mining claims are located in the Chickaloon, Knik River, Girdwood, Hope/Resurrection Creek, and the Moose Pass areas. The Chickaloon and Knik River areas are Native-selected and the Moose Pass area is State-selected. Girdwood, Hope/Resurrection Creek, and the Moose Pass areas are located within the Chugach National Forest (CNF).

Southeast Region: Numerous active federal and State mining claims are located in the southeast region. Active federal mining claims are located on BLM unencumbered lands on the west side of Silver Bay, Baranof Island. Active federal claims are located on State land in the Porcupine Creek area and have federal subsurface estate. These claims were located prior to State selection, and the federal government retains the subsurface estate as long as these claims remain active. Active mining claims are located on State-selected lands in the Porcupine Creek area, Tsirku River area, Juneau area, northern end of Admiralty Island, north of Hyder, head of Trocadero Bay Prince of Wales Island, and on the Duke and Kelp Islands. Most of the active mining claims in the southeast region are located within TNF.

3.1.2 Exploration Activities

The DGGS publishes yearly reports outlining the exploration activity in Alaska. The following information is based on the current information for 2003 (Szumigala *et al.* 2004) covering the entire Ring of Fire planning area.

Alaska Peninsula/Aleutian Chain Region: No current exploration activity is occurring in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No current exploration activity is occurring in the Kodiak region.

Southcentral Region: Current exploration in the southcentral region is occurring at Shulin Lake, located along the Kahiltna River, approximately 25 miles south of Peters Creek. This is a diamond property being explored by Golconda Resources, Ltd. and Shulin Lake Mining Co. by diamond drilling on a structure about 1.25 miles in diameter.

Southeast Region: Current exploration in the southeast region is occurring at four locations. These include: Greens Creek Mine, Woewodski Island, Union Bay, and Duke Island. Exploration is continuing at the Greens Creek silver mine by Kennecott Minerals Co. to extend the mineralized zones and resources of the mine. Drilling was conducted on the west side of the Gallagher Fault, which truncates the large ore body. Bravo Venture Group with Olympic Resources Group, LLC drilled the Lost Lake silver, lead, zinc prospect, on Woewodski Island, intersecting volcanogenic massive sulfide mineralization consisting of semi-massive and massive sphalerite, galena, and silver. Pacific Northwest Capital Corp., Freegold Ventures Ltd., and Lonmin PLC continued an extensive exploration program on their Union Bay platinum prospect, located near Ketchikan. Additional federal claims were staked and extensive channel sampling and diamond drilling was conducted on the Jaguar, Mt. Burnett, North, and Continental zones. Quaterra Resources, Inc. continued their exploration activities on Duke Island, south of Ketchikan, by staking new claims covering new copper discoveries identified from geophysical anomalies.

3.1.3 Federal and State Field Studies

No known field studies are currently being conducted in the Ring of Fire planning area by any pertinent federal or State agency. The USBOM and BLM, in cooperation with the USGS and DGGS, have completed mineral assessment studies and economic studies throughout the southeast region. Studies were completed for the Chichagof, Hyder, Juneau, Ketchikan, Kupreanof, and Petersburg mining districts.

3.1.4 Geophysical Surveys

Aeromagnetic surveys were conducted during the 1960s through the 1980s (URS 2004). Digital aeromagnetic surveys were conducted in the southcentral region in the early 2000s. Airborne geophysical programs have been flown in the Ketchikan and Stikine areas in the southeast region (Bittenbender *et al.* 2001) in support of the mineral assessment studies conducted for the Ketchikan and Sitka mining districts.

No other known airborne geophysical programs have been conducted by federal or State agencies within the Ring of Fire planning area.

3.1.5 New Deposit Discoveries

The DGGS publishes yearly reports outlining the exploration activity in Alaska. The following information is based on the current information for 2003 (Szumigala *et al.* 2004).

Alaska Peninsula/Aleutian Chain Region: No new discoveries were reported during 2003 in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No new discoveries were reported during 2003 in the Kodiak region.

Southcentral Region: No new discoveries were reported during 2003 in the southcentral region.

Southeast Region: Quaterra Resources Inc. continued their exploration activities on Duke Island, south of Ketchikan, finding new copper discoveries identified from geophysical anomalies.

4.0 PAST AND PRESENT DEVELOPMENT ACTIVITY

Past and present development activity is discussed here to characterize the extent of current mineral industry activity within the entire Ring of Fire planning area. This discussion creates a baseline of understanding regarding the mineralized targets of interest to the mineral industry and to what extent their development activities are occurring. Information for this section comes from numerous sources including the DGGS 2003 *Mineral Industry Activity Report* (Szumagala *et al.* 2004) and URS's *Draft Mineral Occurrence Potential Report* (2004).

4.1.1 Past Development Activity

There has been extensive development activity within the Ring of Fire planning area boundary including large scale mining operations. These operations include the Apollo Mine in the Alaska Peninsula/Aleutian Chain region, the Independence Mine in the southcentral region, and the A-J and Kensington Mines in the southeast region. Extensive placer mining activity has occurred in the Petersville-Cache Creek, Collinsville, Hatcher Pass, Crow Creek, and Hope/Resurrection Creek areas in the southcentral region, and in the Yakutat, Haines-Skagway, Juneau-Admiralty Island, Chichagof-Baranof Island, Stikine, Ketchikan-Hyder, and Duke Island areas in the southeast region, to name a few. Only one inactive prospect (Belle) is located on BLM unencumbered lands within the Ring of Fire planning area, and is located east of Sitka in the southeast region.

Table 2 lists the mineral occurrences in the high mineral potential areas that are located on BLM unencumbered lands and State- and Native-selected lands in the Ring of Fire planning area boundary. Numerous properties located in the southcentral region are located in CNF, and in TNF in the southeast region. This information was derived using BLM's Alaska Mineral Information System (AMIS) (BLM 2004) and the USGS's Alaska Resources Data Files (ARDF) (USGS 2005).

Table 2. Select Mineral Occurrences Located in the High Mineral Potential Areas in the Ring of Fire Planning Area

Deposit Name	ARDF/ Amis No.	Commodities	Deposit Type	Land Status
ALASKA PENINSULA/ALEUTIAN CHAIN REGION				
Native-Selected Lands				
Unnamed	UK002/144-002	Cu, Mo	Unknown	Native-selected
Steeple Point	UK011/144-011	Au, Ag	Hot Springs Au-Ag (Cox 25a)	Native-selected
Unnamed	UN020/143-023	Cu	Porphyry Cu (Cox 17)	Native-selected
Makushin Volcano S	UN003/143-001	S	Fumarolic Sulfur	Native-selected
PMRGX-18	PM025/138-041	Pb, Zn	Unknown	Native-selected
Pyramid	PM023/138-039	Cu, Mo	Porphyry Cu-Mo (Cox 21a)	Native-selected
SOUTHCENTRAL REGION				
Native-Selected Lands				
Kings Bay Placer	95-074	Au	Placer Au (Cox 39a)	USFS/Native-selected
State-Selected Lands				
Crown Point Mine	95-114	Au, Ag, Cu, Pb, Zn	Chugach-type (Bliss 36a.1)	USFS/State-selected
East Point Mine	95-095	Au, Ag	Chugach-type (Bliss 36a.1)	USFS/State-selected
Skeen-Lechner	95-116	Au, Ag, Pb, Zn	Chugach-type (Bliss 36a.1)	USFS/State-selected
Falls Creek Mine	95-113	Au, Ag	Chugach-type (Bliss 36a.1)	USFS/State-selected
California Creek	95-115	Au, Pb, Zn	Chugach-type (Bliss 36a.1)	USFS/State-selected
Jones	95-160	Au	Placer Au (Cox 39a)	USFS/State-selected
Mine 7-1/2	95-361	Au, Ag	Chugach-type (Bliss 36a.1)	USFS/State-selected

Table 2 (continued). Select Mineral Occurrences Located in the High Mineral Potential Areas in the Ring of Fire Planning Area

Deposit Name	ARDF/ Amis No.	Commodities	Deposit Type	Land Status
Canyon Creek	95-267	Au	Placer Au (Cox 39a)	USFS/State-selected
Crow Creek Mine	AN104/85-254	Au	Placer Au (Cox 39a)	USFS/State-selected
Raggedtop Mountain	AN106/85-322	Au	Chugach-type (Bliss 36a.1)	USFS/State-selected
Jewell/Monarch[1]	AN107/85-101	Au	Chugach-type (Bliss 36a.1)	USFS/State-selected
Brenner	AN108/85-296	Au, Mo, Pb, Zn	Chugach-type (Bliss 36a.1)	USFS/State-selected
Agostino	AN109	Au	Chugach-type (Bliss 36a.1)	USFS/State-selected
Summit Mountain	AN111/85-323	Au	Chugach-type (Bliss 36a.1)	USFS/State-selected
Bahrenberg Mine[2]	AN110/85-297	Au, Ag, Cu, Pb, Zn	Chugach-type (Bliss 36a.1)	USFS/State-selected
Monarch Mine	85-295	Au, Ag, Cu, Mo	Chugach-type (Bliss 36a.1)	USFS/State-selected
SOUTHEAST REGION				
BLM unencumbered Lands				
Belle	114-163	Ag, Cu, Au	Unknown	BLM
Native-Selected Lands				
Situk Beach	YA007	Au, Fe, PGE, Ti	Beach placer (Cox 39a)	Native-selected
Yakutat Beach	YA002/108-010	Au, Fe, Ti	Beach placer (Cox 39a)	Native-selected
Crystal	119-030	Qtz crystals	Unknown	Native-selected
Westlake	CR214/119-060	Cu, Pb, Au, Zn	Unknown	Native-selected
Hope	CR213	Au, Ag, Cu	Unknown	Native-selected
Bluebird	CR214	Au	Low-sulfide Au-Qtz (Cox 36a)	Native-selected
State-Selected Lands				
Nancy	CR107/119-082	Cu	Unknown	USFS/State-selected
Cable Creek	CR106	Au, Cu, Zn	Kuroko massive sulfide (Cox 28a)	State-selected
Judd Harbor	122-003	Fe, Ni, Cr	Alaskan PGE (Cox 9)	USFS/State-selected
Tsiruku River	109-037	Au, Ag	Placer Au (Cox 39a)	State-selected
Le Blondeau	SK050/109-103	Au, Ag	Polymetallic veins (Cox 22c)	State-selected
Salmon Creek	JU131/112-168	Au	Placer Au (Cox 39a)	State-selected
Goldstein	JU133/112-196	Ag, Au, Cu	Low-sulfide Au-Qtz (Cox 36a)	State-selected
Hallum	JU144/112-129	Au	Low-sulfide Au-Qtz (Cox 36a)	State-selected
Cottonwood Creek	SK049/109-024	Au	Placer Au (Cox 39a)	State-selected
Nugget Creek	SK048/109-034	Au	Placer Au (Cox 39a)	State-selected
Big Nugget Mine	109-057	Au	Placer Au (Cox 39a)	State
Porcupine Creek	SK041/109-036	Au	Placer Au (Cox 39a)	State
KODIAK REGION				
State-Selected Lands				
None				
Native-Selected Lands				
None				

Notes: [1] 3,100 tons averaging 1.75 oz/ton gold and 0.75 oz/ton silver
[2] Reserves at 344 tons

Ag = silver
Au = gold
Cr = chromium
Cu = copper
Fe = iron
Mo = molybdenum
Ni = nickel
Pb = lead
PGE =platinum group elements
Qtz = quartz
S = sulfur
Ti = tin
USFS = U.S. Forest Service
Zn = zinc

4.1.2 Present Development Activity

The DGGS publishes yearly reports outlining the development activity in Alaska. The following information is based on the current information for 2003 (Szumigala *et al.* 2004) covering the entire Ring of Fire planning area.

Alaska Peninsula/Aleutian Chain Region: No current development activity is occurring in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No current development activity is occurring in the Kodiak region.

Southcentral Region: No current lode development activity is occurring in the southcentral region. Placer gold development occurred in the Petersville-Cache Creek, Collinsville, and Hatcher Pass areas.

Southeast Region: Current development in the southeast region is occurring at two locations. These include: The Greens Creek Mine and Kensington Mine in the Juneau area. Development is continuing at the Greens Creek silver mine by Kennecott Minerals Co. and Hecla Mining Co. consisting of access drifting and underground diamond drilling. Coeur Alaska continued to permit the Kensington Mine in cooperation with federal, State, and local agencies. These properties are located within TNF. No development work was reported on placer deposits in the southeast region (Szumigala *et al.* 2004).

4.1.3 Mining Activity

The DGGS publishes yearly reports outlining the mining/production activity in Alaska. The following information is based on the current information for 2003 (Szumigala *et al.* 2004) covering the entire Ring of Fire planning area.

Alaska Peninsula/Aleutian Chain Region: No current mining activity is occurring in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No current mining activity is occurring in the Kodiak region.

Southcentral Region: Three small placer operations reported mining activity in the southcentral region on Crow, Canyon, and Quartz Creeks. Crow Creek is the only placer operation located on State-selected lands within the southcentral region.

Southeast Region: The Greens Creek Mine was the only producing mine in the southeast region. Reported mill throughput was 781,200 tons of ore with metal recovery of 76,200 tons of zinc, 24,800 tons of lead, 11,707,000 ounces of silver, and 99,000 ounces of gold.

5.0 INDUSTRIAL MINERALS

Industrial minerals have been identified within the Ring of Fire planning area as discussed in the URS's *Mineral Occurrence Potential Report* (2004). All of the occurrences discussed are located in the southeast region. Occurrences include gypsum on Chichagof Island, asbestos on Admiralty and Annette Islands, graphite near Stikine, fluorite near Wrangell, mica on Sitklan Island, wollastonite on Prince of Wales Island, and limestone, barite, and gemstones occur throughout the area. Limestones and marbles, pure enough to be considered for development, occur on Prince of Wales and Dall Islands. None of these deposits occur on or near BLM unencumbered or State- or Native-selected lands, and therefore are not considered as part of this report.

6.0 SALABLE MINERALS

Salable minerals including sand and gravel, building stone, pumice, clay, and limestone are common throughout the Ring of Fire planning area (URS 2004). Production of sand and gravel during 2003 is reported by the State of Alaska (Szumagala *et al.* 2004) to include a small amount from Bristol Bay Borough lands in the Alaska Peninsula/Aleutian Chain region. Totals include 5,138,000 tons of sand and gravel from 16 operations in the southcentral region and 1,124,200 tons of sand, gravel, and rock from nine operations in the southeast region. There are no known current salable mineral activities on BLM unencumbered or State- or Native-selected lands within the Ring of Fire planning area.

Building stone, including limestone and marble, has been reported to be quarried primarily in the southeast region. Prince of Wales and Dall Islands have large quantities of pure limestone and marble quarried (URS 2004). Kodiak Island, the Turnagain Arm area, both sides of lower Cook Inlet, and the Matanuska-Susitna Valley, have had dimension stone quarried for riprap and construction purposes (URS 2004).

Pumice deposits occur throughout the Alaska Peninsula/Aleutian Chain region (URS 2004). As there is no foreseeable development potential for this material due to the great distances from the markets, this material will not be considered as part of this report.

Clay deposits occur in the southcentral region in the Bootleggers Cove clay in the Anchorage area, Sheep Mountain in the Matanuska Valley, near Homer, and Moose Pass on the Kenai Peninsula (URS 2004). There is an extremely small foreseeable development potential for this material due to the lack of markets. This material will not be considered as part of this report.

7.0 REASONABLY FORESEEABLE DEVELOPMENT BASELINE SCENARIO ASSUMPTIONS AND DISCUSSION

In this section the discussion is concentrated upon mineral occurrences located on BLM unencumbered lands and the State- and Native-selected lands. This is where the estimated disturbances and cumulative impacts from future mineral resource development are identified and discussed by the alternatives derived during the PRMP/FEIS process.

7.1 Locatable Minerals Economic Assumptions

The following section is a discussion of the economic viability of mining within the Ring of Fire planning area. The purpose of this discussion is to present mine deposit models, estimate amount of activity by model, and estimate the amount of disturbance of the activities through the year 2020. All discussions are based upon the following assumptions.

- All potentially productive areas are open to mineral entry, except those closed by law, regulation, or executive order (e.g., wild and scenic rivers, natural resource areas, special recreation management areas, and areas of critical environmental concern). Lands discussed in this report include BLM unencumbered lands and State- and Native-selected lands.
- Land conveyances will be completed and withdrawals will be lifted by 2010, which should allow for additional exploration.
- Additional exploration in some areas will increase the related reserve base to make mining economically feasible.
- Current management decisions influence current willingness to invest in exploration for long-term development, beyond 2020. In particular, restrictions on access now may preclude future development.
- The mine deposit models created for this report are hypothetical mining and milling scenarios made without exploration of potential mine sites or significant information about ore bodies and environmental conditions. All disturbance estimates would be increased or decreased by different terrain, ore grade, and mine development requirements. However, the bases for the estimates are active mines of a similar nature.

7.2 Mining Process Discussion

The mining process generally consists of exploration, development, extraction, processing, and reclamation.

Mineral exploration begins with prospecting, which is generally inexpensive and results in little environmental impact. Access to remote areas is generally the most expensive part of prospecting in Alaska, but other significant expenses include geochemical sampling, geophysical surveying, satellite remote sensing, and other sophisticated methods for identifying mineral deposits. After identifying a valuable target on open public (federal) land, the prospector will stake and record claims. A claimant begins target testing to confirm the presence of a deposit and determine its size, shape, characteristics, and mineral grade. This requires drilling test holes over an extended area. Because of the expense, drilling is generally limited to the extent necessary to identify sufficient reserves, which would support the costs of development.

Helicopter use can limit surface impacts where road building would otherwise be required. If the target location appears to be economic, the prospector will apply for appropriate permits to develop and operate a mine.

Mine development prepares the site for extraction, and primarily involves establishing the infrastructure necessary to mining. This includes power and water supplies, support and mineral processing facilities, and transportation facilities such as roads and airplane landing sites. Surface locations for ore stockpiles, waste rock, heap leach piles (if used), and tailings impoundments are also prepared. For an open pit mine, initial stripping of surface soils and overburden uncovers the ore body. For an underground mine, shafts or adits, drifts, crosscuts, ramps, and raises are excavated. Development generates substantial capital costs, and involves environmental impacts over the area of development. A large mine with facilities might cover a few thousand acres, with much of the surface disturbance occurring during development.

Extraction (or mining) is generally defined as drilling, blasting, loading, and hauling the ore out of the mine. Waste material may be used to backfill large mined-out areas in surface or underground mines. Continued mining will result in growing waste dumps, heap leach piles, tailings ponds, and other surface disturbances. With placer mining, generally a short section of a surface stream is relocated, the old streambed is cleared, and exposed gravels are processed through sluices. The stream is returned to its former location as part of the reclamation of the area. Suction dredging of placer deposits does not require stream relocation because a pump suctions sediment from the stream bottom to process through sluices.

Mineral processing at a mine site concentrates the ore material before shipment to a smelter or refinery. Exceptions to this include some copper ores, which may be produced on site. Concentrating includes crushing and grinding the ore, then putting the resulting material through physical or chemical processes to separate the valuable minerals from waste tailings. These tailings are disposed of in tailings ponds near the site, and the water may be recycled for reuse at the mine. The tailings may contain trace amounts of minerals, waste rock, and chemicals from processing. At some locations, tailings from old mines are remined with modern processes that allow additional mineral recovery. Tailings may be used to backfill underground stopes (voids). Tailings ponds are engineered to high standards to prevent discharge of acid runoff.

Reclamation is complete when the area is returned to beneficial non-mining use. Common practices include capping waste dumps and tailings piles with soil, removing buildings and roads, planting appropriate ground cover, and directing water flow to minimize acid runoff. This requires long-term monitoring to assure the efforts work as expected.

7.3 Forecast Deposit Model Types and Mining Production Rates

The following section uses information from similar reserves to estimate disturbance that could result from development of deposit types located on unencumbered BLM land and State- and Native-selected lands within the Ring of Fire planning area. The primary model source was Mineral Deposit Models (Cox and Singer 1986). Where information from the deposit or nearby deposits was substantially different from the Cox and Singer model, the local information was used rather than the models. Appendix 1 lists the deposits, models, reserves/resources, their estimated disturbed acreages and mine production rates.

7.3.1 Alaska Peninsula/Aleutian Chain Region

Hot-spring Gold-Silver (Cox and Singer Model 25a)

Modeled deposit reserves: not modeled by Cox and Singer.

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Steeple Point	UK011	None reported[1]	Pilcher, 2000	Native-selected

Notes: [1]Samples contain arsenic, copper, gold, molybdenum, silver, and zinc; all at low value; no reserve estimate.

The USGS ARDF (Pilcher 2000 and 2002) describes over 80 locations of epithermal gold vein deposits in this portion of the Ring of Fire planning area, with additional locations not assigned deposit types. Prospects with reserve estimates range from 30,000 to 110,000 short tons (st). No prospects have been mined. This analysis used a reserve of 135,000 st and production of 100 st per day (stpd). At that production rate, disturbance is estimated to be 40 acres for basic facilities with no specific terrain or mining considerations identified. If necessary, employee housing, marine access, and road construction would be an additional 30 acres, based on an 8.5-mile road.

Conclusion: Based on recurring interest in some occurrences and prospects, it is likely one or more areas will be further explored in the reasonably foreseeable future with disturbance less than 5 acres. The time required for conveyance, exploration, permitting, and development would put the start of production near the end of the 15-year period. Any development on or near BLM-managed lands could disturb up to 70 acres of the surface.

Porphyry Copper (Cox & Singer Model 17)

Modeled deposit reserves: median deposit is 155 million st, with 80 percent between 21 and 1,212 million st (Cox and Singer 1986).

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Unnamed	UN020/143-023	None reported	Wilson 1996	Native-selected
Pyramid	PM023/138-039	126 million st	Pilcher 2002	Native-selected
Unnamed	UK002/144-002	None reported	Pilcher 2000	Native-selected

Notes: st = short ton

The Pyramid location was explored in 1974 to 1975 and found to have up to 0.403 percent copper and 0.25 percent molybdenum. The reserves were estimated at 126 million st, which compares favorably with the median of the Cox and Singer model. Much less is known about the unnamed occurrences, though descriptions suggest they may be porphyry copper or similar deposits.

A reserve of 126 million st could produce 17,000 stpd for 21 years. The resulting disturbance might reach 1,340 acres by the end of the mine life. However, the reported quality is 0.403 percent copper and 0.25 percent molybdenum, which in the present market would not support the costs of production.

Conclusion: For all sites, additional exploration might occur within the foreseeable future and might result in 5 acres of disturbance during the next 15 years. The limited information on the unnamed occurrences indicates substantial exploration may be required to determine development potential, and any development is unlikely before 2020. Developing the Pyramid location requires permitting after land conveyance, and may not occur within 15 years due to ore quality.

Fumarolic Sulfur (Cox & Singer Model not identified)

Modeled deposit reserves: not identified.

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Makushin Volcanic S	UN003/143-01	Reserve estimate 9,000 st high grade ore and up to 122,500 st low grade ore	Wilson 1996	Native-selected

Notes: st = short ton

This occurrence may extend to 30 acres, though the high grade area is estimated to be about 5 acres. The depth of the mineral is up to 16 feet, but estimated to be only 2 feet for the high grade area. The location is within the crater of a remote volcano with active fumaroles and vents, making it an unlikely target in the current sulfur market. Sulfur from oil and natural gas entirely replaced mining in 2000, and is expected to meet sulfur demand in the foreseeable future (Ober 2004). Given the limits of the crater and size of the reserve, any development might result in 40 to 60 acres of disturbance, depending on the ore grade cutoff used. Production rates range from 13 to 93 stpd for 2 to 4 years.

Conclusion: This location and any similar locations will not be developed in the foreseeable future.

Lead-Zinc (Cox & Singer Model not identified)

Modeled deposit reserves: not identified.

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
PMRGX-18	PM025	None reported	Pilcher, 2002	Native-selected

Information about this occurrence is limited, suggesting that the time necessary to explore and permit exceeds the foreseeable period. This occurrence may be similar to the Apollo Mine in the same region, though that operation targeted gold and silver. The Cox and Singer Model 22c (Polymetallic veins) is identified as representative of the Apollo Mine reserve (Pilcher 2002). This model indicates median 8,400 st, with 80 percent between 320 and 220,460 st (Cox and Singer 1986). A mine at the average of the model, reserves of 8,400 st, would require a very high grade ore body to be economic, and might result in 40 acres of disturbance. Production might occur at a rate of 12.5 stpd for less than 2 years.

Conclusion: With the time necessary for conveyance, exploration, and permitting, this occurrence will not be developed in the foreseeable future. Exploration might occur in the foreseeable future, with 5 acres disturbance.

7.3.2 Kodiak Region

No mineral deposits were identified on BLM unencumbered or State- and Native-selected lands in the Kodiak region. No deposit modeling was completed for this area.

7.3.3 Southcentral Region

Gold-Quartz Veins (Chugach-type) (Cox and Singer Model 36a)

Modeled deposit reserves: median deposit is 33,000 st, with 80 percent between 1,100 and 1 million st (Cox and Singer 1986).

Deposit Name	ARDF/ AMIS No.	Resources	Reference	Land status
Jewel/Monarch Mine	AN107/85-101	3,100 st high potential	Bickerstaff and Huss 1998	USFS/State-selected
Brahrenberg Mine	AN110/85-297	344 st	Bickerstaff and Huss 1998	USFS/State-selected
Agostino	AN109	High potential	Bickerstaff and Huss 1998	USFS/State-selected
Raggedtop Mountain	AN106/85-322	None reported	Bickerstaff and Huss 1998	USFS/State-selected
Brenner	AN108/85-296	None reported	Bickerstaff and Huss 1998	USFS/State-selected
Summit Mountain	AN111/85-323	None reported	Bickerstaff and Huss 1998	USFS/State-selected
Crown Point Mine	95-114	None reported	BLM, 2004	USFS/State-selected
East Point Mine	95-095	None reported	BLM, 2004	USFS/State-selected
Skeen-Lechner	95-116	None reported	BLM, 2004	USFS/State-selected
Falls Creek Mine	95-113	None reported	BLM, 2004	USFS/State-selected
California Creek	95-115	None reported	BLM, 2004	USFS/State-selected
Mile 7-½	95-361	None reported	BLM, 2004	USFS/State-selected
Monarch Mine	85-295	None reported	BLM, 2004	USFS/State-selected

Notes: st = short ton
USFS = U.S. Forest Service

The mines identified with high development potential have remained inactive since the 1930s or 1940s (Bickerstaff and Huss 1998). These locations have had very little activity for up to 70 years, so it appears that they have little economic value. If development were to occur, disturbance would be somewhat less than 70 acres with mill and marine facilities required by an underground operation. A reserve of 344 to 3,100 st would produce at 1 to 6 stpd for 1 or 2 years from startup, and require about 12 employees.

Conclusion: Additional exploration would likely result in 1 to 5 acres disturbance at any occurrence, with 13 acres for all. Additional development is not expected in the foreseeable future.

Placer Gold (Cox & Singer Model 39a)

Modeled Deposit Reserves: median is 1.2 million st, with 80 percent between 24,250 and 55 million st (Cox and Singer 1986).

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Crow Creek	AN104/85-254	1.2 million cubic meters	Bickerstaff and Huss 1998	USFS/State-selected
Jones	95-160	None reported	BLM, 2004	USFS/State-selected
Canyon Creek	95-267	None reported	BLM, 2004	USFS/State-selected
Kings Bay Placer	95-074	None reported	BLM, 2004	USFS/Native-selected

Notes: USFS = U.S. Forest Service

The State of Alaska Annual Placer Mining Application (APMA) for the Crow Creek Mining Company indicated 4.5 acres currently disturbed, with 1 acre disturbed and reclaimed during the year (Alaska Department of Natural Resources [ADNR] 2004). This is indicative of placer operations throughout the area.

No estimate of production rate was made because of the variability possible in placer mining.

Conclusion: Other than the operating Crow Creek Mine, there is no indication that any of these occurrences would begin production in the foreseeable future. Additional exploration might result in 1 to 5 acres disturbance at any occurrence, with 3 acres total for locations other than Crow Creek. The Crow Creek site is likely to disturb and reclaim 1 acre per year for 15 years.

7.3.4 Southeast Region

Alaskan Platinum Group Elements (Cox and Singer Model 9)

Modeled Deposit Reserves: not modeled by Cox and Singer.

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Judd Harbor/Duke Island	PR001/122-003	None reported, averages of 0.037 ppm Pt, 0.033 ppm Pd, and 0.010 ppm Rh	Berg 1999	State-selected

Notes: ppm = parts per million; Pt = Platinum; Pd = Palladium; Rh = Rhodium

Additional exploration would be required to determine the economic feasibility of this location. Quality parameters suggest the grade is too low to be economic, even at recent record prices. No reserve estimate was possible, so no production rate was estimated.

There is exploration in the area, with new copper discoveries on Duke Island. Development of other discoveries may make this occurrence economic in the future, but it is currently too speculative to suggest it will happen.

Conclusion: This occurrence will not be explored or developed in the foreseeable future.

Placer Gold (Cox and Singer Model 39a)

Modeled deposit reserves: median is 1.2 million st, with 80 percent between 24,250 and 55 million st (Cox and Singer 1986).

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Nugget Creek	SK048/109-034	None reported	Crafford 2001	State-selected
Cottonwood Creek	SK049/109-024	None reported	Crafford 2001	State-selected
Tsiruku River	109-037	None reported	BLM, 2004	State-selected
Salmon Creek	JU131/112-168	None reported	Barnett and Miller 2003	State-selected
Situk Beach	YA007	None reported	Hawley 1999	Native-selected
Yakutat Beach	YA002/108-010	36 million cubic meters	Hawley 1999	Native-selected
Big Nugget Mine	109-057	None reported	BLM, 2004	State-selected
Porcupine Creek	SK041/109-036	152,000 cubic yards	Crafford 2001	State-selected

The APMA (ADNR 2004) for the Crow Creek Mining Company in the southcentral region indicated 4.5 acres currently disturbed, with one acre disturbed and reclaimed during the year. This is indicative of placer operations throughout the state.

The Porcupine Creek area, including the Porcupine Creek mine shown above, has reported production of 79,650 troy ounces of gold between 1898 and 1985. Recent production at the mine has been limited to times of high gold prices. Reserve estimates indicate there may be more than 1,611 troy ounces of gold remaining in the unmined gravels. These reserves have not supported sustained production at gold prices since 1945.

No estimate of production rate was made because of the variability possible in placer mining.

Conclusion: There is no indication that any of these occurrences would begin production in the foreseeable future. If any placer mine is developed on or near BLM land in this region, disturbance at any time is expected to be five acres or less per operation, with direct employment of three to six miners. Exploration may disturb one to five acres at any location, with a total disturbance of eight acres for these occurrences.

Underground Copper (Cox and Singer Model not identified)

Modeled deposit reserves: not identified.

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Nancy	CR107/119-082	None reported	Grybeck 2004	USFS/State-selected

Information about this occurrence is limited, suggesting that the time necessary to explore and permit exceeds the foreseeable period. Such exploration might disturb up to five acres of surface. This copper occurrence may be similar to the Nelson and Tift Mine (ARDF PR005) or White Knight prospect (ARDF KC053) in the same region.

The Nelson and Tift Mine is identified as a copper skarn model 18b, though the mine sold only gold (Berg, 1999). It had reserves estimated at 1,300 st. The larger White Knight prospect is identified as a polymetallic vein model 22c though staked claims were for gold (Berg 1999). The reserve median for this model deposit is 8,400 st, with 80 percent between 320 and 220,460 st (Cox and Singer 1986). Those reserves would allow for 12.5 stpd for less than two years, and require only eight employees. Surface disturbance would be up to 70 acres. A mine of this size would require a very high grade ore body.

Conclusion: With the time necessary for conveyance, exploration, and permitting, this occurrence will not be developed in the foreseeable future.

Low-Sulfide Gold Quartz (Cox and Singer Model 36a)

Modeled deposit reserves: median is 33,000 st, with 80 percent between 1,100 and one million st (Cox and Singer 1986).

Deposit name	ARDF/AMIS no.	Resources	Reference	Land status
Goldstein	JU133/112-196	None reported	Barnett 2003	State-selected
Hallum	JU144/112-129	None reported	Barnett 2003	State-selected
Westlake	CR214/119-060	None reported	Grybeck 2004	Native-selected
Bluebird	CR214	None reported	Grybeck 2004	Native-selected

Limited information and previous workings at these sites suggest little additional development potential, unless additional exploration identifies economic reserves. Even so, if the deposits were Low-Sulfide Gold-Quartz Veins, as ARDF indicates, initial reserves would have been about 33,000 st. Mine production would be about 35 stpd for 2.7 years, if most of the ore remains after the early mining. This would be similar to the Chugach-type mine with disturbance of up to 70 acres for development and about five acres during exploration. Development would require low access costs or high grade ore.

Conclusion: Exploration and development are unlikely before 2020.

Kuroko Massive Sulfide (Cox and Singer Model 28a)

Modeled deposit reserves: median is 1.6 million st, with 80 percent between 133,000 and 20 million st (Cox and Singer 1986).

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Cable Creek	CR106	None reported	Grybeck 2004	State-selected

The occurrence at Cable Creek is at roadside and has been sampled by government and industry. The quality is low, but suggests a possible Kuroko-type massive sulfide deposit nearby. Additional exploration is required to identify such a deposit. Such exploration would result in about 5 acres disturbance. If a Kuroko-type deposit is identified, it might contain 1.6 million st. This would support production of 660 stpd for over 7 years and result in over 120 acres surface disturbance. While this could result in a large to very large mine for the region, it is speculative to suggest such a deposit could be located, explored, and developed in the foreseeable future.

Conclusion: Although development is unlikely before 2020, additional exploration may occur at this site, resulting in up to 5 acres of disturbance.

Polymetallic veins (Cox and Singer Model 22c)

Modeled deposit reserves: median is 8,300 st, with 80 percent between 320 and 220,000 st (Cox and Singer 1986).

Deposit Name	ARDF/AMIS No.	Resources	Reference	Land Status
Le Blondeau	SK050/109-103	None reported	Crafford 2001	State-selected
Belle	114-163	None reported	BLM, 2004n	BLM
Hope	CR213	None reported	Grybeck 2004	Native-selected

The Le Blondeau prospect information is limited to sample results and a possible model type. Additional exploration is required, and might result in about 5 acres disturbance during exploration. The small deposit size for a silver-gold-cobalt mine makes development uneconomic, so exploration would be required to identify adequate reserves to support the cost of extraction. Production for this small of a deposit is estimated to be 12.5 stpd for less than 2 years, or higher production for a shorter period.

The Belle and Hope occurrences are not classified as polymetallic vein deposits, but have been included in this model based on minerals reported. While the model gives production and disturbance information that may apply, the lack of information makes it unlikely that any development will occur in the foreseeable future.

Conclusion: Although development is unlikely, additional exploration may occur at Le Blondeau, resulting in up to 5 acres of disturbance. No activity is likely at Belle and Hope occurrences.

8.0 SURFACE DISTURBANCE DUE TO LOCATABLE MINERAL ACTIVITY

Information used to develop the estimated surface disturbance resulting from locatable mineral activity with the Ring of Fire planning area was derived from the BLM's AMIS database, the USGS ARDF open-file reports, the URS's *Draft Mineral Occurrence Potential Report* (2004), USBOM mineral terranes map, federal and state mining claim databases, and DGGS yearly 2003 *Mineral Industry Report*. All mineral activities discussed are restricted to BLM unencumbered or State- and Native-selected lands. The following discussion is written to fit the development alternatives derived during the PRMP/FEIS process.

8.1 Estimate of Current Surface Disturbance Resulting from Locatable Mineral Activity

Alaska Peninsula/Aleutian Chain Region: No locatable mineral activity is currently being conducted in this region (Szumigala *et al.* 2004). No active mining claims are located on BLM unencumbered or State- and Native-selected lands.

There is no current surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: No locatable mineral activity is currently being conducted in this region (Szumigala *et al.* 2004). No active mining claims are located on BLM unencumbered or State- and Native-selected lands.

There is no current surface disturbance resulting from locatable mineral activity on BLM unencumbered or State and Native-selected lands in the Kodiak region.

Southcentral Region: Mineral activity reported during 2003 for the southcentral region includes one exploration project (Shulin Lake) and three small placer operations (Crow, Canyon, and Quartz creeks) (Szumigala *et al.* 2004). Active placer mining claims on Crow, Canyon, and Quartz creeks are located within CNF. Active placer mining claims located in the Petersville-Cache Creek, Collinsville, and Hatcher Pass areas (Szumigala *et al.* 2004) are on State land with federal subsurface estate, but are currently not actively being operated. No active mining claims are located on BLM unencumbered lands.

A total of four placer properties and 13 gold-quartz vein (Chugach-type) properties are located within the High Mineral Potential Areas listed in Table 2 and Appendix 1, and shown on Figure 5. Of these properties the only active placer operation, the Crow Creek Mine, is used mainly as a tourist recreational panning site. All the remaining placer properties and the gold-quartz vein properties are currently inactive.

Estimated current surface disturbance for the entire southcentral region includes 5 acres for the Shulin Lake exploration project and 15 acres for the Crow Creek, Canyon Creek, and Quartz Creek mines. Total estimated surface disturbance in the southcentral region resulting from active locatable mineral activity would be 20 acres.

Estimated current surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the southcentral region includes 5 acres for the Crow Creek Mine.

Southeast Region: Mineral activity reported during 2003 for the southeast region includes four exploration projects (Greens Creek Mine, Union Bay, and Duke and Woewodski islands), two development projects (Greens Creek and Kensington mines), one hard rock mining operation (Greens Creek Mine), and one placer operation (Big Nugget Mine) (Szumigala *et al.* 2004).

A total of eight placer properties and three low-sulfide gold-quartz; one each Kuroko massive sulfide, Alaskan platinum group elements (PGE), and polymetallic vein; and five unknown properties are located within the High Mineral Potential Areas listed in Table 2 and Appendix 1 and shown on Figure 6. Two placer operations on Porcupine Creek (Big Nugget Mine and Porcupine Creek) are located on State land with federal subsurface estate and are currently inactive. One historical inactive lode prospect (Belle) is located on BLM unencumbered land east of Sitka. Of these operations only the Big Nugget Mine has had any active mining during the recent past, but is currently inactive. No active mining claims are located on BLM unencumbered lands.

Estimated current disturbance for the entire southeast region area includes 20 acres for the exploration projects (Greens Creek Mine, Union Bay, and Duke and Woewodski islands), 140 acres for the development projects (Greens Creek and Kensington mines), and 200 acres for the mining operation (Greens Creek Mine). Total estimated surface disturbance in the southeast region resulting from active locatable mineral activity is 360 acres.

There is no current surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the southeast region.

8.2 Estimate of <u>Future Surface Disturbance</u> for Mines, Mills, Roads, and Locatable Mineral Related Infrastructure that May Result from Projections of Future Activity

Alaska Peninsula/Aleutian Chain Region: There is expected to be a very small amount of reasonably foreseeable future locatable mineral activity in the Alaska Peninsula/Aleutian Chain region. Future exploration activities are estimated to occur at three locations (Steeple Point, PMRGX-18, and Pyramid). Three other locations (Makushin Volcano S and two unnamed) are unlikely to be developed. These locations are listed in Table 2 and Appendix 1, and shown on Figure 4.

Total estimated future surface disturbances resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Alaska Peninsula/Aleutian Chain region is 15 acres.

Kodiak Region: There is no estimated reasonably foreseeable future surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Kodiak region.

Southcentral Region: There is expected to be a very small amount of reasonably foreseeable future locatable mineral activity in the southcentral region. Future yearly exploration activities are estimated to continue at one location (Shulin Lake), possible development of placer operations in the Petersville-Cache Creek, Collinsville, and Hatcher Pass areas, and continued mining at three placer operations on Crow, Canyon, and Quartz creeks.

A total of four placer properties and 13 gold-quartz vein (Chugach-type) properties are located within the High Mineral Potential Areas listed in Table 2 and Appendix 1, and shown on Figure 5. Of these properties the only active placer operation, the Crow Creek Mine, is used mainly as a tourist recreational panning site. All the remaining placer properties and the gold-quartz vein properties are currently inactive.

Estimated future surface disturbance for the entire southcentral region includes 5 acres for the Shulin Lake project, 15 acres for the Crow Creek Mine, three acres for the Kings Bay, Jones, and Canyon Creek placers, 5 acres for the Petersville-Cache Creek, Collinsville, and Hatcher Pass area placer operations, and 13 acres for the lode properties. Total estimated surface disturbance in the southcentral region resulting from active locatable mineral activity would be 36 acres if all the above properties were actively mining.

Total estimated future surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands is 31 acres, as listed in Appendix 1.

Southeast Region: There is expected to be a continuation of the activities occurring on the four exploration projects (Greens Creek Mine, Woewodski Island, Union Bay, and Duke Island), two development projects (Greens Creek and Kensington Mines), one hard rock mining operation (Greens Creek Mine) and one placer operation (Big Nugget Mine) in the southeast region (Szumigala *et al.* 2004).

A total of eight placer properties and three low-sulfide gold-quartz; one each Kuroko massive sulfide, Alaskan PGE, and polymetallic vein; and five unknown properties are located within the High Mineral Potential Areas listed in Table 2 and Appendix 1, and shown on Figure 6.

Estimated future disturbance for the entire southeast region includes 30 acres for the exploration projects (also includes Cable Creek and Le Blondeau), 140 acres for the development projects, 200 acres for the mining operation, and 8 acres for the placer operations. Total estimated future surface disturbance in the southeast region resulting from locatable mineral activity is 378 acres.

Total estimated future surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands is 18 acres, as listed in Appendix 1.

8.3 Estimate of Staged Future Surface Reclamation of Disturbance Activity

Alaska Peninsula/Aleutian Chain Region: If the exploration activities were to occur at three locations (Steeple Point, PMRGX-18, and Pyramid) there would be 15 acres of disturbance requiring reclamation. As there is no current exploration activity in the Alaska Peninsula/Aleutian Chain region, an estimate of future staged reclamation cannot be made.

There is no reasonably foreseeable estimated staged future surface reclamation of disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: There is no reasonably foreseeable estimated staged future surface reclamation of disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Kodiak region.

Southcentral Region: If all the estimated activities were to occur for the entire southcentral region, disturbance would include 5 acres for the Shulin Lake project, 15 acres for the Crow Creek Mine, 3 acres for the Kings Bay, Jones, and Canyon Creek placers, 5 acres for the Petersville-Cache Creek, Collinsville, and Hatcher Pass area placer operations, and 13 acres for the lode properties. A total estimated surface disturbance of 36 acres would need to be reclaimed in the southcentral region.

The only reasonably foreseeable estimated staged future reclamation of disturbance would be possible activity on the federal mining claims located on State land in the Petersville-Cache Creek, Collinsville, and Hatcher Pass area. That estimate would be no more than 5 acres per year resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the southcentral region.

Southeast Region: If all the estimated activities were to occur for the entire southeast region, disturbance would include 30 acres for the exploration projects (also includes Cable Creek and Le Blondeau), 140 acres for the development projects, 200 acres for the mining operation, and 8 acres for the placer operations. A total estimated surface disturbance of 378 acres would need to be reclaimed in the southeast region.

The only reasonable foreseeable estimated staged future reclamation of disturbance would be possible activity on the federal mining claims located on State land in the Porcupine Creek area (Big Nugget Mine). That estimate would be no more than 5 acres per year from exploration, development, or mining work conducted on placer gold deposits.

8.4 Estimated Total Surface Disturbance

(Total surface disturbance = current + future disturbance)

Alaska Peninsula/Aleutian Chain Region: The reasonably foreseeable estimated total surface disturbance in the Alaska Peninsula/Aleutian Chain region is zero acres of current disturbance plus 15 acres of future disturbance, for a total of 15 acres on BLM unencumbered or State- and Native-selected lands.

Kodiak Region: There is no reasonably foreseeable estimated total surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands on Kodiak Island.

Southcentral Region: The reasonably foreseeable estimated total surface disturbance in the southcentral region is five acres of current disturbance plus 31 acres of future disturbance, for a total of 36 acres on BLM unencumbered or State- and Native-selected lands.

Southeast Region: The reasonably foreseeable estimated total surface disturbance in the southeast region is zero acres of current disturbance plus 18 acres of future disturbance, for a total of 18 acres on BLM unencumbered or State- and Native-selected lands.

8.5 Estimated Total Net Surface Disturbance

(Total net surface disturbance = current + future disturbance – reclamation)

Alaska Peninsula/Aleutian Chain Region: The reasonably foreseeable estimated total net surface disturbance in the Alaska Peninsula/Aleutian Chain region is zero acres of current disturbance plus 15 acres of future disturbance minus zero acres of reclamation, for a total of 15 acres on BLM unencumbered or State- and Native-selected lands.

Kodiak Region: There is no reasonably foreseeable estimated total net surface disturbance resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Kodiak region.

Southcentral Region: The reasonably foreseeable estimated total net surface disturbance in the southcentral region are 5 acres of current disturbance plus 31 acres of future disturbance minus 5 acres for reclamation, for a total net of 31 acres on BLM unencumbered or State- and Native-selected lands.

Southeast Region: The reasonably foreseeable estimated total net surface disturbance in the -southeast region are zero acres of current disturbance plus 18 acres of future disturbance minus 5 acres for reclamation, for a total net of 13 acres on BLM unencumbered or State- and Native-selected lands.

8.6 Estimated Number and Type of Infrastructure Facilities that May Impact Air Quality

Alaska Peninsula/Aleutian Chain Region: There will be no reasonably foreseeable infrastructure facilities that may impact air quality resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: There will be no reasonably foreseeable infrastructure facilities that may impact air quality resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Kodiak region.

Southcentral Region: Infrastructure facilities affecting air quality for one placer operation, located on State-selected land in the Petersville-Cache Creek area, would be limited to a small diesel or gasoline generator (50 kilowatts [kW]) and/or small water pumps (less than 40 horsepower), if the operation is located away from existing electric power lines. The one exploration effort might require similar infrastructure during the short summer season. The development project located on State-selected lands within CNF would also require diesel generators for electrical power (up to 1,200 kW peak load), if power lines to the location were not feasible. In addition, there would be emissions from heavy equipment and some potential for windborne dust from disturbed areas that were not stabilized. Operations would be required to meet applicable federal and State air quality standards for permitting.

The small size of the operations, as well as the short period of operation would create a minor impact on the local air quality.

Southeast Region: For the one exploration prospect and placer operation located on State-selected lands, each operation might require a small diesel or gasoline generator (50 kW) and/or small water pumps (up to 40 horsepower). The one development prospect, located on State-selected lands, might require diesel generators (800 to 3,534 kW peak load), if existing power lines to the location are not feasible. In addition, there would be emissions from heavy equipment and some potential for windborne dust from disturbed areas that were not stabilized. Operations would be required to meet applicable federal and state air quality standards for permitting.

The small size of the operations, as well as the short period of operation would create a minor impact on the local air quality.

8.7 Estimated Quantity and Quality of Produced Water Disposed on the Surface

Alaska Peninsula/Aleutian Chain Region: There will be no reasonably foreseeable water disposed on the surface resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Alaska Peninsula/Aleutian Chain region.

Kodiak Region: There will be no reasonably foreseeable water disposed on the surface resulting from locatable mineral activity on BLM unencumbered or State- and Native-selected lands in the Kodiak region.

Southcentral Region: Water for the one possible operating placer operation, located on State-selected land in the Petersville-Cache Creek area, would be limited to the amount put through a gravity separation process (500 gallons per minute, possibly recycled), plus domestic use of 9,000 to 18,000 gallons annually. The one exploration effort would require smaller quantities of water for drilling and domestic use, assuming a much shorter work year. The development project, located on State-selected lands within CNF, would also require water for processing and domestic use. The size of the reserve makes on-site flotation milling unlikely, but if it occurs, it would be a closed circuit for water use, using only the initial input and makeup water for the amount remaining in the tailings. About 11,000 gallons would be required for the initial day of processing, and about 400,000 gallons per year for makeup water. It is assumed that mine discharge will generally provide this water, and surface water will be required infrequently and there would be no untreated discharge of produced water. It is estimated that employees will require up to 280,000 gallons per year of potable water from a local water source, which will be discharged appropriately. Operations would be required to meet applicable federal and State water quality standards for permitting.

The small size of the operations, as well as the short period of operation would create a minor impact on the local water quality.

Southeast Region: Each of the four placer operations located on State-selected lands and one placer operation located on Native-selected lands might require water for a gravity separation process (500 gallons per minute, possibly recycled), plus domestic use of 9,000 to 18,000 gallons annually. The exploration effort would require smaller quantities of water for drilling and domestic use, assuming a much shorter work year. The development prospect, located on State-selected lands, might require water for processing and domestic use. The on-site flotation milling is less likely for the smaller reserve size, but probable for the larger estimate. It would be a closed circuit for water use, using only the initial input and makeup water for the amount remaining in tailings. Initial requirements would be 96,000 gallons for the first day, plus approximately 3.6 million gallons of makeup water during each year of operation. It is assumed that mine discharge will generally provide this water, and surface water will be required infrequently, and there would be not untreated discharge of produced water. It is estimated that employees will require 175,000 to 665,000 gallons per year of potable water from a local water source, which will be discharged appropriately. Operations would be required to meet all applicable federal and State water quality standards for permitting.

The small size of the operations, as well as the short period of operation would create a minor impact on the local water quality.

9.0 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO DISCUSSION BY ALTERNATIVE

9.1 Alternative 1 – No Action (Current Management)

Under the No Action Alternative (Current Management) BLM-managed lands are currently withdrawn from mineral entry either by the Alaska Native Claims Settlement Act d(1) withdrawals or by State- or Native selection. Currently no locatable mineral activity is occurring in the Alaska Peninsula/Aleutian Chain region or in the Kodiak region. All current activity is occurring in the southcentral and southeast regions.

Most of the locatable mineral activity in the southcentral region does not occur on BLM unencumbered land or State- or Native-selected lands. Only one placer operation is located on State-selected lands and several hard rock operations are located on state land with federal subsurface estate. In the southeast region, one exploration and four placer operations are located on State- and Native-selected lands. Two placer operations are located on State land with federal subsurface estate.

If locatable mineral activity were to occur on every existing operation, as allowable by present BLM authority, an estimated total of 5 acres could potentially be disturbed in the Ring of Fire planning area. The activity would be restricted to the Petersville-Cache Creek and Hatcher Pass areas in the southcentral region and the Porcupine Creek area in the southeast region. Due to the small size of the existing operations, as well as the short period of operation there would be a minor impact on the local air and water quality.

9.2 Alternative B – Resource Development

Under the Resource Development Alternative, all future mineral activities would be allowed in the Ring of Fire planning area as all withdrawals would be repealed. There is no reasonably foreseeable future locatable mineral activity in the Kodiak region. All reasonably foreseeable future mineral activity will occur in the Alaska Peninsula/Aleutian Chain, southcentral, and southeast regions. However, due to its sensitive nature, the Neacola Mountains-Blockade Glacier area could remain closed to mineral entry.

All of the locatable mineral activity in the Alaska Peninsula/Aleutian Chain region is located on Native-selected lands. Most of the locatable mineral activity in the southcentral region area does not occur on BLM unencumbered land or State- or Native-selected lands. Only one placer operation is located on State-selected lands and several hard rock and placer operations are located on State land with federal subsurface estate. In the southeast region, one exploration and four placer operations are located on State and Native-selected lands. Two placer operations are located on State land with federal subsurface estate.

If locatable mineral activity were to occur on every existing operation, as allowable by present BLM authority, an estimated total of 59 acres could potentially be disturbed in the Ring of Fire planning area. The activity would be restricted to the Alaska Peninsula/Aleutian Chain, southcentral, and southeast regions. Due to the small size of the existing operations, as well as the short period of operation there would be a minor impact on the local air and water quality.

9.3 Alternative C – Resource Conservation

Under the Resource Conservation Alternative, no future mineral entry would be allowed in the Ring of Fire planning area as all withdrawals would remain in place. However, locatable mineral activity would still be allowed in existing "grandfathered" operations in the southcentral and southeast regions. These operations occur in the Petersville-Cache Creek, Collinsville, and Hatcher Pass area in the southcentral region and the Porcupine Creek area in the southeast region, as identified in the No Action Alternative. Currently no locatable mineral activity is occurring in the Alaska Peninsula/Aleutian Chain or Kodiak regions.

If locatable mineral activity were to occur on every existing operation, as allowable by present BLM authority, an estimated total of 5 acres could potentially be disturbed in the Ring of Fire planning area. Under this alternative no further disturbance would be allowed. Due to the small size of the existing operations, as well as the short period of operation there would be a minor impact on the local air and water quality.

9.4 Alternative D – Proposed Action

Under the Proposed Action, all future mineral activities would be allowed in the Ring of Fire planning area, as all withdrawals would be repealed. There is no reasonably foreseeable future locatable mineral activity in the Alaska Peninsula/Aleutian Chain or Kodiak regions. However, due to its sensitive nature, the Neacola Mountains-Blockade Glacier area of the southcentral region could remain closed to mineral entry.

Most of the locatable mineral activity in the southcentral region does not occur on BLM unencumbered land or State- or Native-selected lands. Only one placer operation is located on State-selected lands and several hard rock and placer operations are located on State land with federal subsurface estate. In the southeast region, one exploration and four placer operations are located on State- and Native-selected lands. Two placer operations are located on State land with federal subsurface estate.

If locatable mineral activity were to occur on every existing operation, as allowable by present BLM authority, an estimated total of 59 acres could potentially be disturbed in the Ring of Fire planning area, less depending upon classification of the identified sensitive areas. The activity would be restricted to the Petersville-Cache Creek and Hatcher Pass areas in the southcentral region and the Porcupine Creek area in the southeast region. Due to the small size of the existing operations, as well as the short period of operation there would be a minor impact on the local air and water quality.

10.0 REFERENCES

Alaska Department of Natural Resources (ADNR). 2004. Alaska Placer Mining Application (APMA) Mining Applications. November 2004. http://www.dnr.state.ak.us/cgi-bin/discus/

Arctic Environmental Information and Data Center (AEIDC). 1982. Mineral terranes of Alaska -- 1982; University of Alaska, Anchorage, 6 figures (1:1,000,000 scale).

Barnett, J.C., and Miller, L.D. 2003. Juneau quadrangle, Alaska Resource Data Files (ARDF); U.S. Geological Survey (USGS) Open-File Report 03-456, p. 304-05, 308-09, 331-332, 25 October 2004. http://ardf.wr.usgs.gov/

Berg, H. 1999. Ketchikan quadrangle, ARDF; USGS, 25 October 2004. http://ardf.wr.usgs.gov/

Bickerstaff, D., and Huss, S.W. 1998. Anchorage quadrangle, ARDF; USGS Open-File Report 98-599, p 222-224, 228-242, 25 October 2004. http://ardf.wr.usgs.gov/

Bittenbender, P.E., Bean, K.W., and Still, J.C. 2001. Stikine airborne geophysical survey followup, central southeast Alaska; BLM Technical Report 37, 116 p.

Bittenbender P.E., Still, J.C., Mass, K.N., McDonald, M.E., Jr. 1999. Mineral resources of the Chichagof and Baranof Islands area, southeast Alaska; BLM Technical Report 19, 222 p., 3 plates.

Bureau of Land Management (BLM). 2004. Alaska Minerals Information Service (AMIS); November 2004. (Available at the BLM Alaska State Office)

Cox, D.P., and Singer, D.A. 1986. Mineral deposit models; USGS Bulletin 1693, 379 p.

Crafford, T.C. 2001. Skagway quadrangle, ARDF; USGS Open-File Report 01-193, p. 87-89, 105-111, 25 October 2004. http://ardf.wr.usgs.gov/

Grybeck, D.J. 2004. Craig quadrangle, ARDF; USGS Open-File Report 2004-1384, p. 236-239, 454-457, 25 October 2004. http://ardf.wr.usgs.gov/

Hawley, C.C. 1999. Yakutat quadrangle, ARDF; USGS Open-File Report 99-333, p. 6-8, 17-18, 25 October 2004. http://ardf.wr.usgs.gov/

Maas, K.M., Bittenbinder, P.E., and Still, J.C. 1995. Mineral Investigations in the Ketchikan Mining District, Southeastern Alaska: U.S. Bureau of Mines (USBOM) Open-File Report 11-95, 606 p.

Nelson, S.W, and Miller, M.L., 2000, Assessment of mineral resource tracts in the Chugach National Forest, Alaska; USGS Open-File Report 00-026, 16 p.

Ober, J.A. 2004. Mineral commodity summary 2004, Sulfur; USGS, 5 December 2004. http://minerals.usgs.gove/minerals/pubs/commodity/sulfur/sulfumcs04.pdf

Pilcher, S.H. 2000. Umnak quadrangle, ARDF; USGS Open-File Report 00-118, p. 5-6, 25-26, 25 October 2004. http://ardf.wr.usgs.gov/

Pilcher, S.H. 2002. Port Moller quadrangle, ARDF; USGS Open-File Report 02-47, p. 47-49-52-53, 25 October 2004. http://ardf.wr.usgs.gov/

Resource Data, Inc. (RDI), Alaska Earth Sciences, Inc., and USBOM. 1995. Mineral terranes and known mineral deposit areas; Published by USBOM, 5 p.

Still, J.C., Bittenbender, P.E., Bean, K.W., and Gensler, E.G. 2002. Mineral assessment of the Stikine area, central southeast Alaska: BLM Technical Report 51, 560 p.

Szumigala, D.J., Hughes, R.A., and Harris, R.H. 2004. Alaska's mineral industry 2003; Alaska Division of Geological and Geophysical Surveys (DGGS) Special Report 58, 71 p.

URS Corporation (URS). 2004. Mineral Occurrence Potential Report for the Ring of Fire Planning Area; 58 p., 33 figures.

U.S. Geological Survey (USGS). 2005. Alaska Resource Data Files; March 2005. http:// http://ardf.wr.usgs.gov/

Wilson, F.H. 1996. Unalaska quadrangle, ARDF; USGS Open-File Report 96-270, p. 5-6, 30, 25 October 2004. http://ardf.wr.usgs.gov/

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12.0 STATEMENT OF QUALIFICATIONS

Mark P. Meyer, Physical Scientist and Darla D. Pindell, Mineral Economist, BLM, Division of Energy and Solid Minerals.

Figures

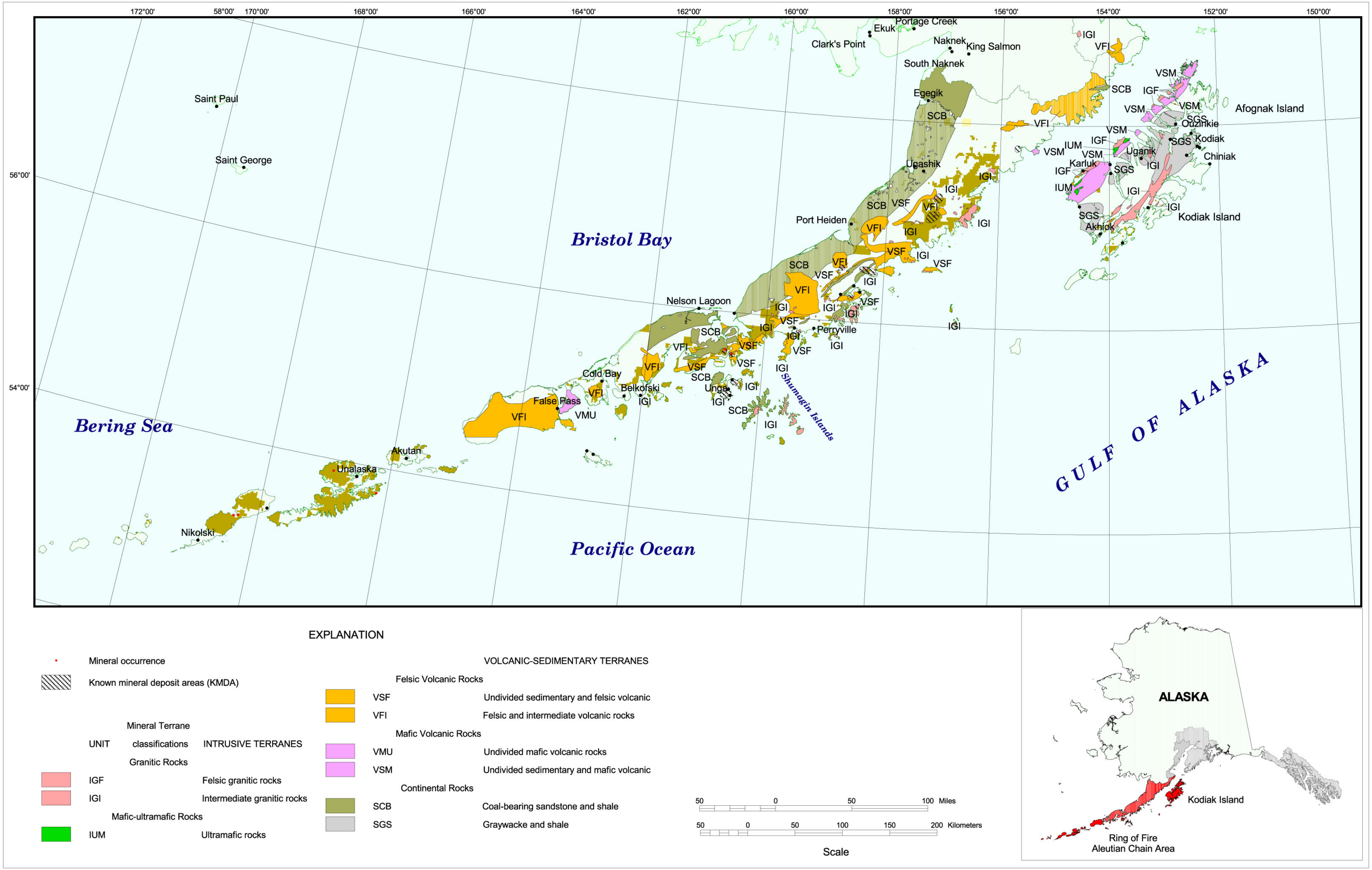

Figure 1. -- Locatable mineral occurrence and mineral terrane map of the Ring of Fire RMP, Alaska Peninsula/Aleutian Chain, and Kodiak Island planning areas.

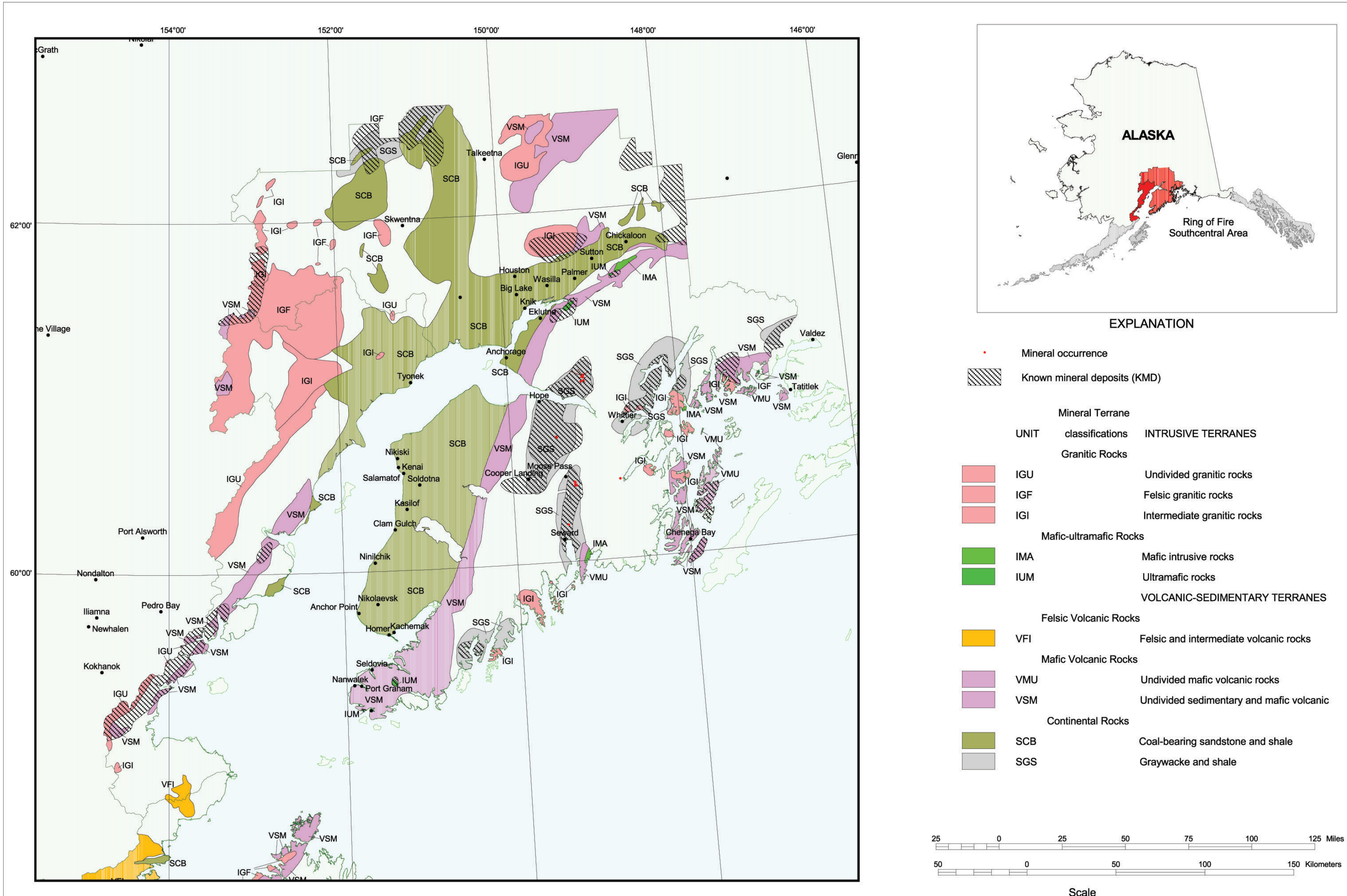

Figure 2. -- Locatable mineral occurrence and mineral terrane map of the Ring of Fire RMP, Southcentral Alaska planning area.

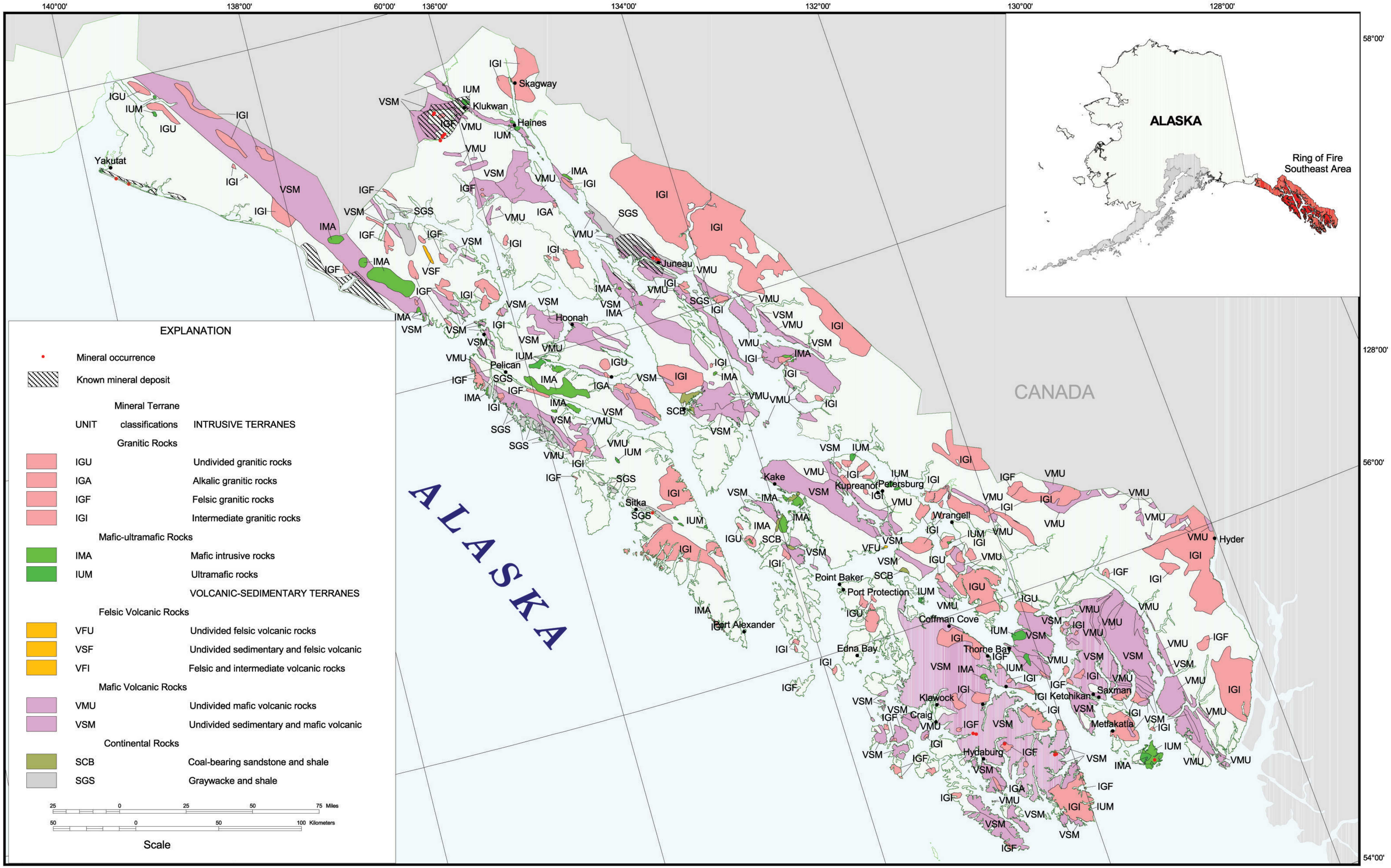

Figure 3. -- Locatable mineral occurrence and mineral terrane map of the Ring of Fire RMP, Southeast Alaska planning area.

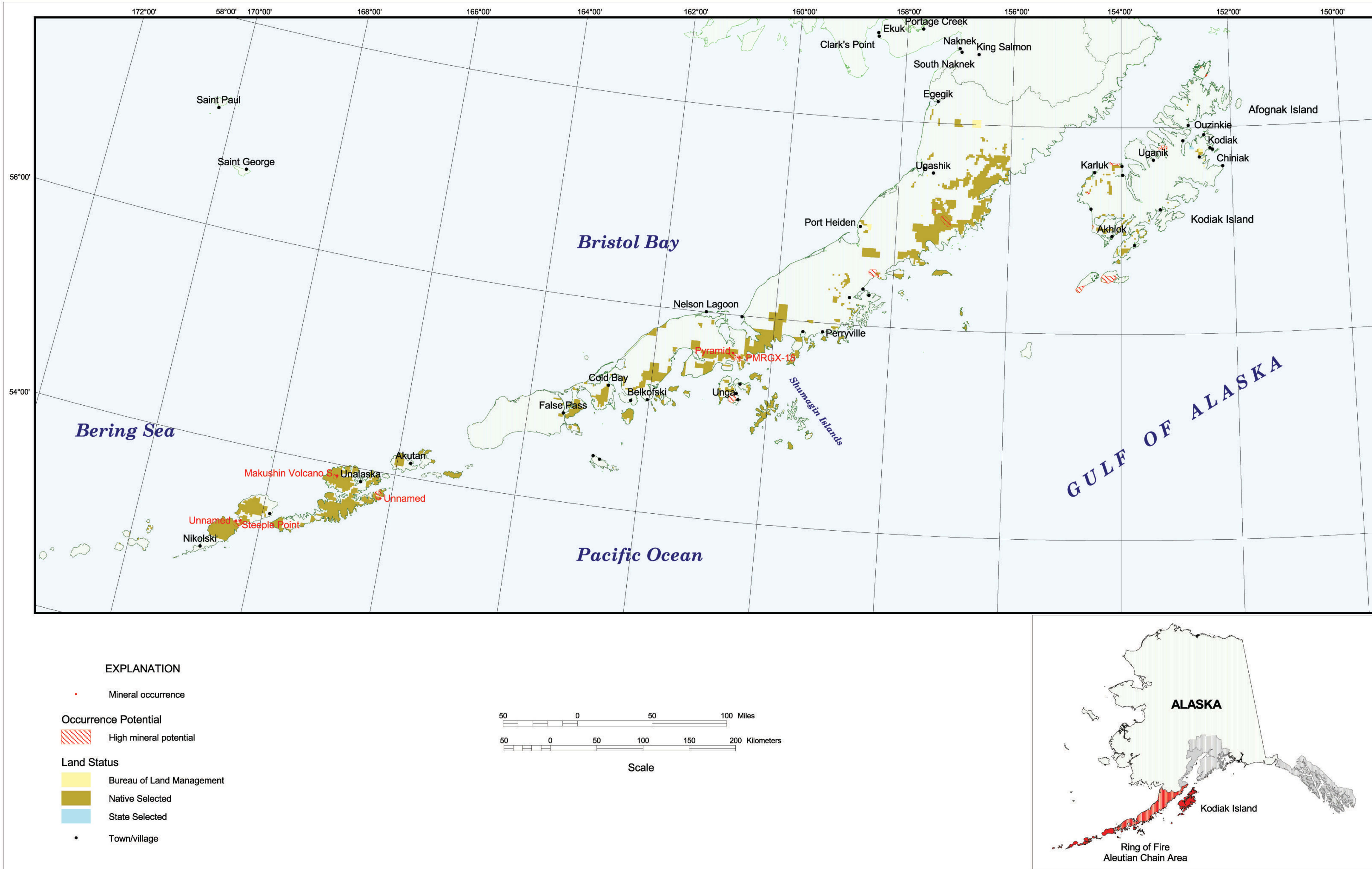

Figure 4. -- Locatable mineral potential map of the Ring of Fire RMP, Alaska Peninsula/Aleutian Chain, and Kodiak Island planning areas.

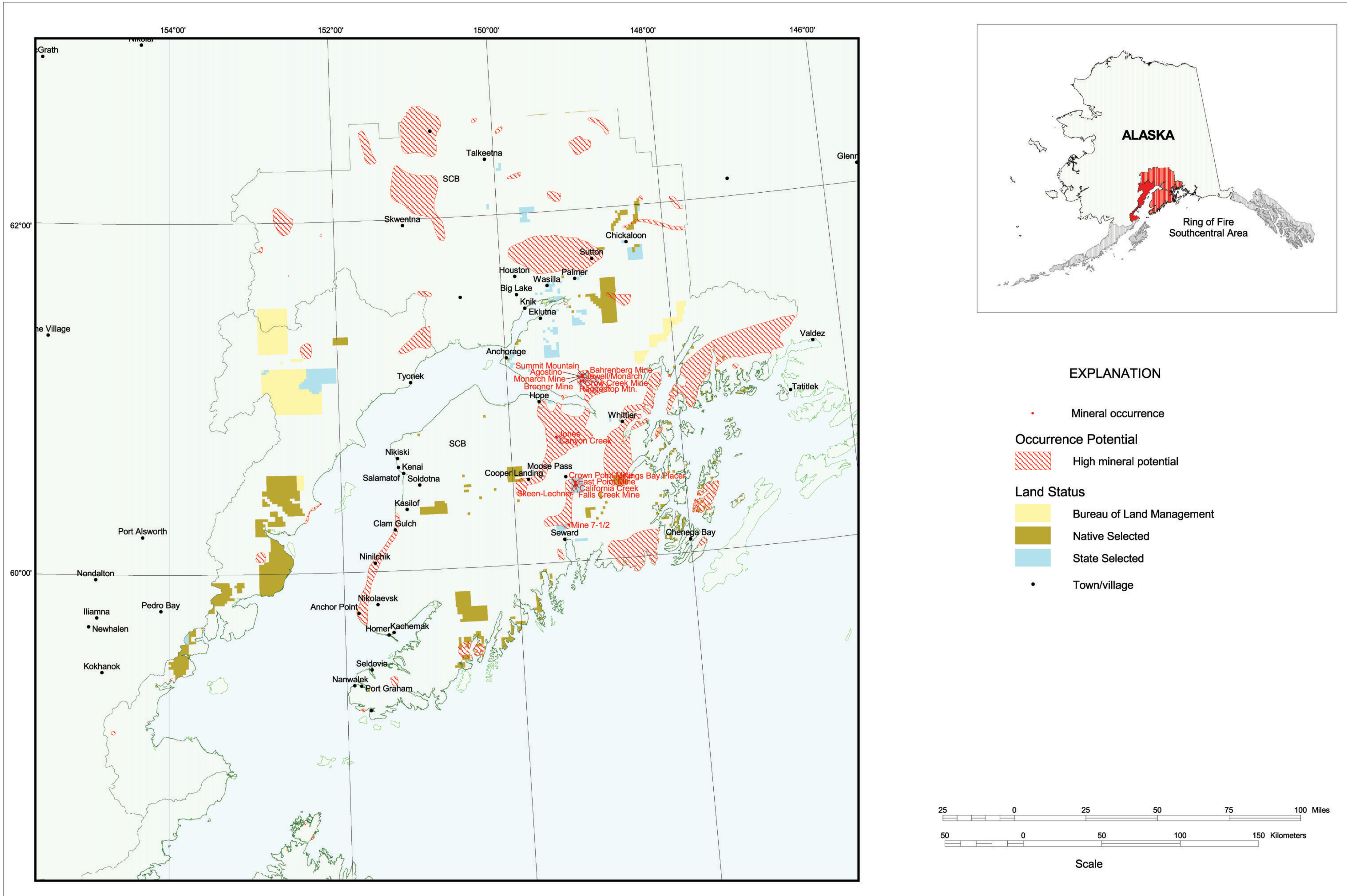

Figure 5. -- Locatable mineral potential map of the Ring of Fire RMP, Southcentral Alaska planning area.

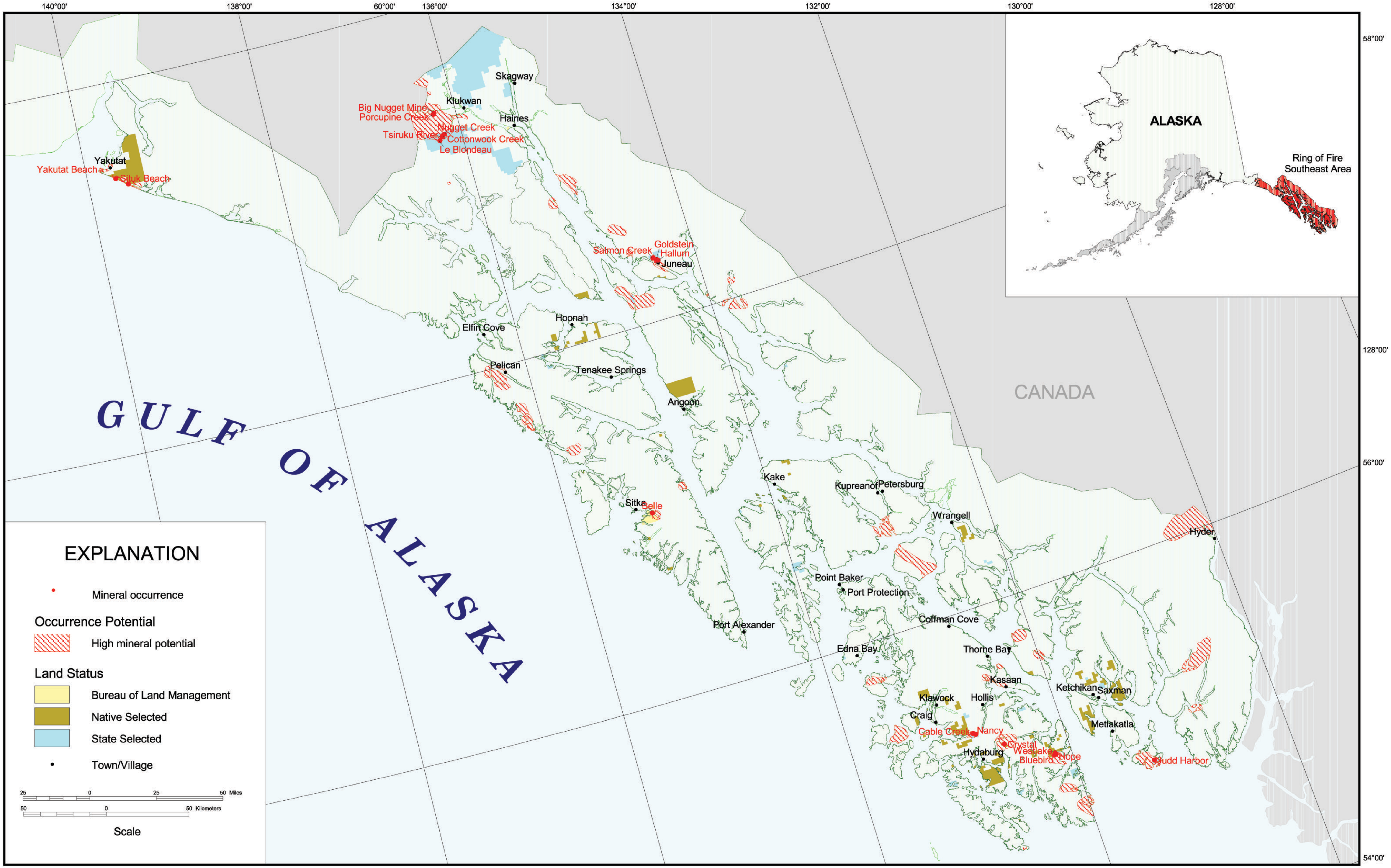

Figure 6. -- Locatable mineral potential map of the Ring of Fire RMP, Southeast Alaska planning area.

APPENDIX 1

Estimated Disturbance from Mineral Development within the Ring of Fire Planning Area

Appendix 1. Estimated Disturbance from Mineral Development within the Ring of Fire Planning Area

PoD	Deposit Name	Status	Deposit Model Type (Cox and Singer)	Reserves/Resources	Mine Production Rates (Estimated)	Disturbed Acreage (Estimated)	Reasonably Foreseeable Alternative B
ALASKA PENINSULA/ALEUTIAN CHAIN							
u	Unnamed	NS	Cu, Mo	Unknown, 126 million st used for analysis	Unknown, 17,000 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres
l	Steeple Point	NS	25a - Hot-spring Au-Ag	Unknown, 135,000 st used for analysis	Unknown, 100 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	5 acres
u	Unnamed	NS	17 - Porphyry Cu?	Unknown, 126 million st used for analysis	Unknown, 17,000 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres
u	Makushin Volcano S	NS	Fumarolic Sulfur	9,000 to 122,500 st	1 to 6 stpd	40 to 60 acres	0 acres
l	PMRGX-18	NS	Pb-Zn	Unknown, 8,400 st used for analysis	Unknown, 12.5 stpd used for analysis	5 acres for exploration, 40 acres for development	5 acres
l	Pyramid	NS	21a - Porphyry Cu-Mo?	126 million st	17,000 stpd	5 acres for exploration, 1,340 acres for development	5 acres
SOUTHCENTRAL							
u	Kings Bay Placer	NS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Crown Point Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	East Point Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Skeen-Lechner	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Skeen-Lechner	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Falls Creek Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	California Creek	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Jones	USFS/SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Mile 7-½	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Canyon Creek	USFS/SS	39a - Placer Au	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
h	Crow Creek (active)	USFS/SS	39a - Placer Au	1.2 million cubic meters	Not estimated	4.5 to 5 acres currently disturbed; 15 acres additional disturbance and reclamation	15 acres
u	Raggedtop Mountain	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Jewel/Monarch Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	3,100 st	6 stpd	1 to 5 acres for exploration, <70 acres for development	1 acre

Appendix 1. Estimated Disturbance from Mineral Development within the Ring of Fire Planning Area (continued)

PoD	Deposit Name	Status	Deposit Model Type (Cox and Singer)	Reserves/Resources	Mine Production Rates (Estimated)	Disturbed Acreage (Estimated)	Reasonably Foreseeable Alternative B
u	Brenner	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Agostino	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Summit Mountain	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Brahrenberg Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	344 st	1 stpd	1 to 5 acres for exploration, <70 acres for development	1 acre
u	Monarch Mine	USFS/SS	36a.1 - Au-Qtz veins (Chugach-type)	Unknown, 344 st used for analysis	Unknown, 1 stpd used for analysis	1 to 5 acres for exploration, <70 acres for development	1 acre
SOUTHEAST ALASKA							
	Belle	BLM	Ag, Cu, Au	Unknown, 8,400 st used for analysis	Unknown, 12.5 stpd used for analysis	5 acres for exploration, 40 acres for development	0 acres
u	Situk Beach (Beach Placer)	NS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Yakutat Beach	NS	39a - Placer Au	36 million cu m	Not estimated	1 to 5 acres	1 acre
	Crystal	NS	Qtz crystals	Unknown	Minimal disturbance for personal collection	Minimal disturbance for personal collection	0 acres
u	Westlake	NS	Cu, Pb, Au, Zn	Unknown, 33,000 used for analysis	Unknown, 35 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres
	Hope	NS	Au, Ag, Cu	Unknown, 8,400 st used for analysis	Unknown, 12.5 stpd used for analysis	5 acres for exploration, 40 acres for development	0 acres
u	Bluebird	NS	36a - Low-sulfide Au-Qtz	Unknown, 33,000 st used for analysis	Unknown, 35 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres
u	Nancy	USFS/SS	Underground Cu	Unknown, 8,400 st used for analysis	12.5 stpd	5 acres for exploration, 40 acres for development	0 acres
u	Cable Creek	SS	28a - Kuroko massive sulfide	Unknown, 1.6 million st used for analysis	Unknown,658 stpd used for analysis	5 acres for exploration, 121 acres for development	5 acres
nd	Judd Harbor/Duke Island	USFS/SS	9 - Alaskan PGE	Unknown	Not determined	Not determined	0 acres
u	Tsiruku River	SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Le Blondeau	SS	22c - Polymetallic veins	Unknown, 8,400 st used for analysis	Unknown, 12.5 stpd used for analysis	5 acres for exploration, 40 acres for development	5 acres
u	Salmon Creek	SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Goldstein	SS	36a - Low-sulfide Au-Qtz	Unknown, 33,000 used for analysis	Unknown, 35 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres
u	Hallum	SS	36a - Low-sulfide Au-Qtz	Unknown, 33,000 used for analysis	Unknown, 35 stpd used for analysis	5 acres for exploration, 40 to 70 acres for development	0 acres

Appendix 1. Estimated Disturbance from Mineral Development within the Ring of Fire Planning Area (continued)

PoD	Deposit Name	Status	Deposit Model Type (Cox and Singer)	Reserves/Resources	Mine Production Rates (Estimated)	Disturbed Acreage (Estimated)	Reasonably Foreseeable Alternative B
u	Cottonwood Creek	SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Nugget Creek	SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Big Nugget Mine	SS	39a - Placer Au	Unknown	Not estimated	1 to 5 acres	1 acre
u	Porcupine Creek	SS	39a - Placer Au	152,000 cubic yards	Not estimated	1 to 5 acres	1 acre

Notes: PoD = Probability of development: h = high, m = moderate, l = low with exploration required, u = unlikely
Status: USFS = U.S. Forest Service, NS = Native-selected , SS = State-selected

Ag = silver
Au = gold
Cu = copper
Pb = lead
PGE = platinum group elements
Mo = molybdenum
Qtz = quartz
st = short ton
stpd = short ton per day
Zn = zinc