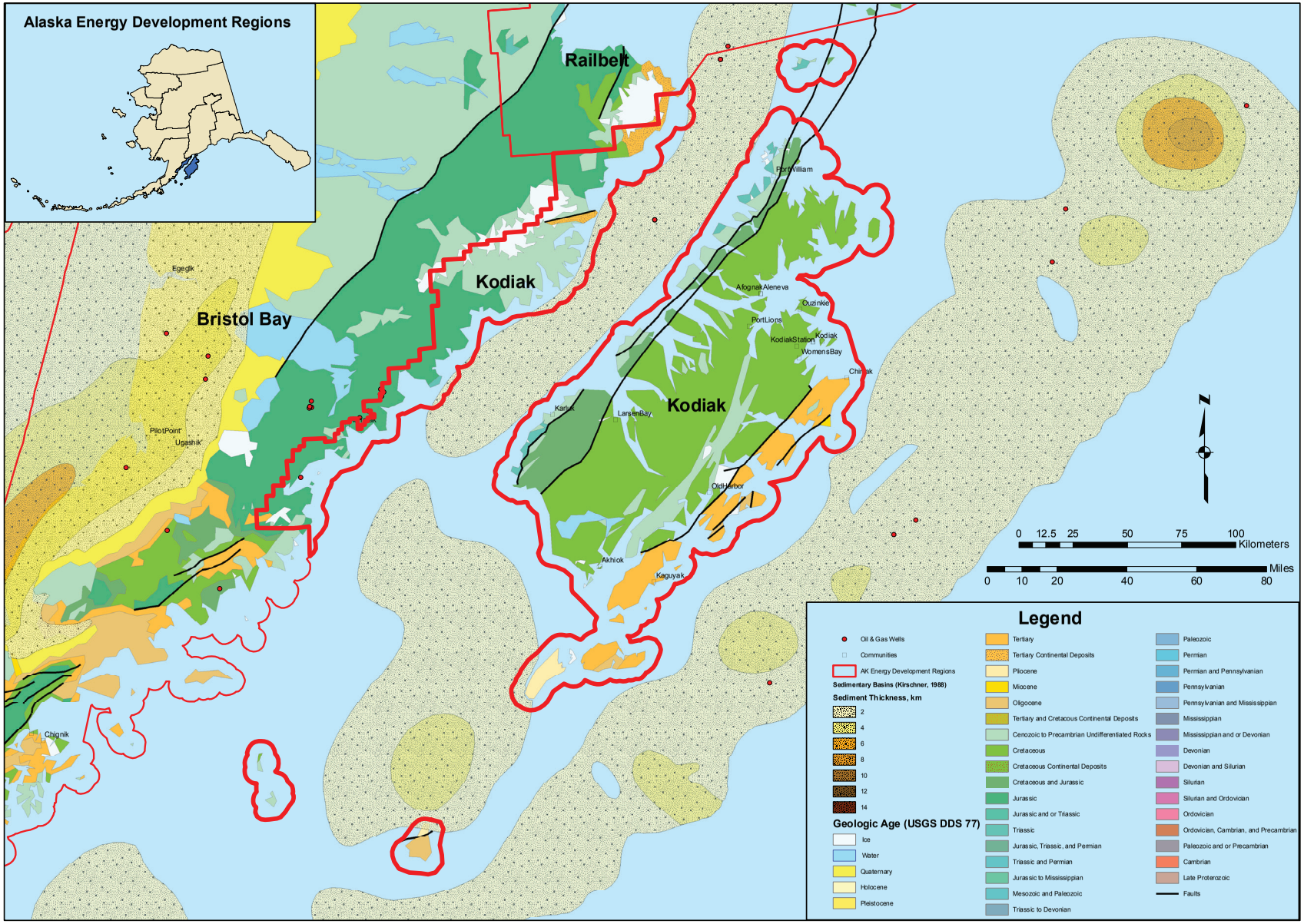
# Geology of the Kodiak Energy Region, Alaska




**Kodiak**

# SUMMARY OF FOSSIL FUEL AND GEOTHERMAL RESOURCE POTENTIAL IN THE KODIAK ENERGY REGION

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## INTRODUCTION

### Purpose of this report

Economic growth and stability in Alaska's rural and urban areas hinges partially, if not primarily, on the availability of affordable and sustainable energy supplies. Recent price increases in oil and gas commodities have created severe economic hardship in many areas of the state that are dependent on diesel and heating oil as their primary source of energy. All sectors of Alaska's economy rely on affordable energy sources with limited price volatility, highlighting the need to diversify the energy portfolio by developing locally available and sustainable resources that are not tied to the global market. Unfortunately, all areas are not created equal in energy accessibility; the resources available for local exploitation vary widely across the state. It is critical that funding decisions for expensive programs to reduce the dependence on diesel for heat and electricity take into account information concerning the entire suite of natural resources that exist in a given area.

This report draws from existing information to provide community and state leaders an objective summary of our current knowledge concerning the potential of locally exploitable fossil fuel and geothermal energy resources in the Kodiak energy region (fig. F1), one of 11 regions recognized by the Alaska Energy Authority in their Energy Plan (AEA, 2009). The potential geologically hosted energy resources considered here include exploitable coal, conventional and unconventional oil and gas, and geothermal resources. This report concludes with recommendations as to what additional data or strategies, if any, would provide the most leveraging in helping to develop new energy resources in the region.

Readers without geological training are encouraged to peruse the geologic summaries of fossil fuel resources and geothermal energy in Chapter A. They provide an overview of the geologic elements that must be present in an area to economically develop coal, conventional oil and gas, unconventional oil and gas, and geothermal resources. These summaries will provide the necessary background to more fully understand the information presented in this chapter.

### Geographic and geologic setting

The Kodiak Development Region encompasses a series of islands across Shelikof Bay from the southeast coast of the upper Alaska Peninsula (sheet 1; fig. F1). Included from northeast to southwest are the Barren Islands, Shuyak, Afognak, Kodiak, and, Sitkalidak islands, the Trinity Islands, and Chirikof Island. Also included in the development region are coastal lands on the upper Alaska Peninsula facing the greater Kodiak Island area separated by the Shelikof Strait. This strip of land extends from Point Douglas southwestward to Mount Kialagvik, at the head of Wide Bay. The largest community in the development region is Kodiak, with a current population of 5,691, followed by Kodiak Station and Women's Bay, with current populations of 1,817 and 830, respectively. Several other, much smaller communities are widely scattered across the region.

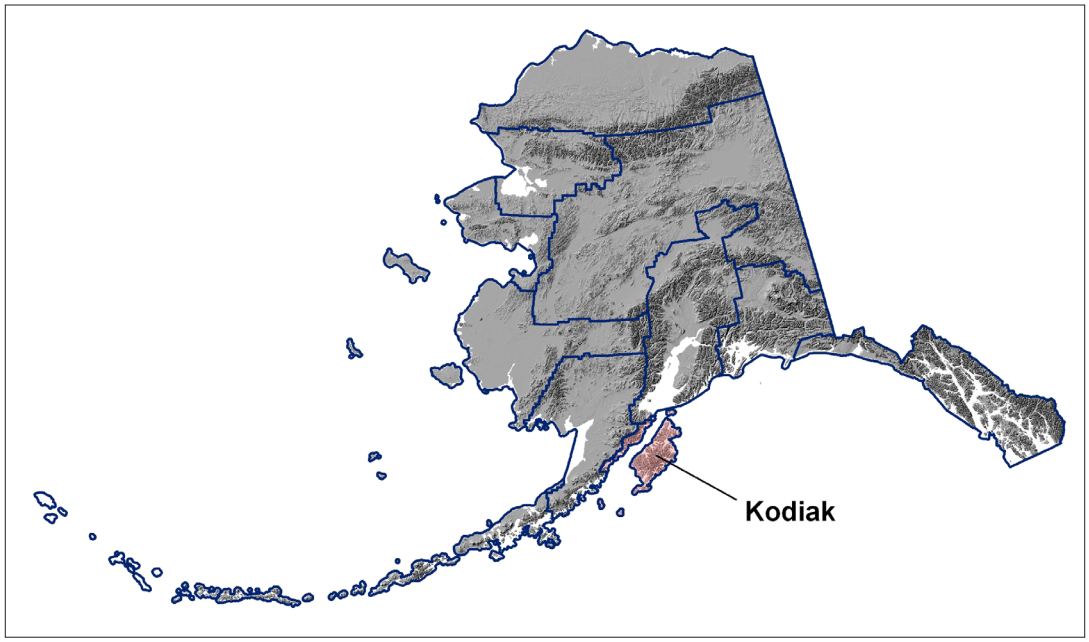


Figure F1. Location map of Kodiak Energy Region.

Most of the land area in the Kodiak Development Region is represented by Kodiak, Afognak, and smaller nearby islands that essentially are the subaerial expression of a northwest-trending mountain belt emerging from the Gulf of Alaska waters, and are an extension of the Kenai Mountains to the northeast. The largest of these islands, Kodiak, hosts rugged mountains with peaks reaching nearly 4,500 feet. Glacially-sculpted, generally northwest-trending fjords are best developed on the northwest side of the island, producing a highly irregular coastline. Inland topography is defined by orthogonal linear ridges and broad glacial valleys. Lowlands, especially on the southwestern end of the island, support numerous small lakes and marshes. Afognak Island shares similar traits, but with more subdued, less rugged topography. The smaller islands to the northeast and southwest are of low to moderate relief. The northwestern boundary of the Kodiak Development Region on the Alaska Peninsula essentially traces the spine of the Aleutian Range from near Point Douglas southwestward to Mount Kialagvik. The rugged topography of the range often extends to the coast, which is scalloped by numerous bays.

Most of the Alaska Peninsula and Aleutian Islands are the product of millions of years of accumulation of volcanic flows and detritus above a subduction zone that has been active for about 200 million years (Trop and Ridgway, 2007; Amato and others, 2007). This process continues today with the oceanic Pacific plate being thrust toward the northwest beneath the North American plate. Magma generated at the plate boundary has intruded the overriding North American plate, resulting in an arcuate array of volcanoes referred to as a volcanic island arc. Major episodes of arc volcanism have occurred at least three times on the Alaska Peninsula over the past approximately 200 million years (Reed and Lanphere, 1969; Wilson, 1985; Amato and others, 2007). Volcanism along the Aleutian chain was underway by about 35 million years ago (Wilson, 1981). Today, arc volcanism is the dominant geologic process shaping the Aleutian Islands and Alaska Peninsula. Paleozoic and early Mesozoic metamorphic and sedimentary rocks that comprised a major crustal block collided with continental North America in early to middle Triassic time and became the catchment for thick accumulations of sediments that were shed from the earliest continental arc on the Alaska Peninsula. The rocks forming the catchment and some of the early sediments filling the basin are believed to be petroleum source rocks for the adjacent Bristol Bay and Cook Inlet petroleum basins (Detterman and Hartsock, 1966; Decker and others, 2008). Subsequent cycles of tectonic subsidence and uplift since Late Cretaceous time are responsible for the coal-bearing rocks in the northwestern area of the development region (Detterman and others, 1996), as well as many of the petroleum reservoir rocks in the adjacent petroleum basins (Calderwood and Fackler, 1972; Detterman and others, 1996; Helmold and others, 2008). Cenozoic-age faulting and folding near the plate margin result from compression and transpression associated with the subduction zone and form most of the potential hydrocarbon traps for these petroleum systems and conduits for hydrothermal fluids in geothermal systems. The Kodiak Island chain is a direct expression of the same subduction processes that formed the Chugach Mountains of the Kenai Peninsula. Erosional remnants of a continental volcanic arc preserved on the northwestern sides of Kodiak and Afognak islands are the same age as the earliest volcanic arc rocks found on the Alaska Peninsula and as far north as the Talkeetna Mountains (Hill and Morris, 1977). These arc rocks are in fault contact with high-grade metamorphic rocks to the southeast that represent remnants of an extinct subduction zone that was active prior to about 190 million years ago (Carden and others, 1977). Between about 190 and 120 million years ago, subduction moved southeastward more than 100 miles to near its present-day position in the Gulf of Alaska. Since that time, sediments shed oceanward from the continental margin have been scraped off of the subducting oceanic plate and piled against the continental edge to form the rugged mountains on the eastern side of Kodiak and Afognak islands (Connelly, 1978; Bradley and others, 2009). Approximately 59 million years ago, this pile of highly-deformed strata was intruded by magma that formed the Kodiak batholith (Farris and others, 2006). None of these pre-Cenozoic rocks have value in terms of energy resources, owing to their igneous origins, high metamorphic grade, lack of organic composition, or high degree of deformation. However, a sedimentary basin developed along the southeastern coast of the islands and offshore to the southeast on the Kodiak Shelf during Eocene time (sheet 2) and includes marine and terrestrial strata that possess modest fossil fuel potential (Nilsen and Moore, 1979).

## GEOLOGIC ENERGY RESOURCE POTENTIAL IN THE KODIAK ENERGY REGION

### Mineable coal resource potential

Coal is not known to occur in large quantities in the Kodiak Energy Region. The few reported occurrences are concentrated in middle or late Oligocene strata of the Sitkinak Island Formation (Nilsen and Moore, 1979). Exposures of these strata are relatively small, discontinuous, and located near the southern end of the central tidal flat on Sitkinak Island, Tanginak Anchorage on the northeastern coast of Sikalidak Island, and Boulder Bay on the eastern coast of Kodiak Island (fig. F2; Nilsen and Moore, 1979). References to coal in the Kodiak Energy Region are rare, probably owing to its meager occurrences in the area. Most of what is known about coal on Kodiak Island is found in a 1972 report by D.L. McGee, which is a compilation of earlier, and often reconnaissance-level, studies. McGee (1972) reports coal beds on Kodiak Island to be thin and likely not an economic resource. However, no bed thicknesses or

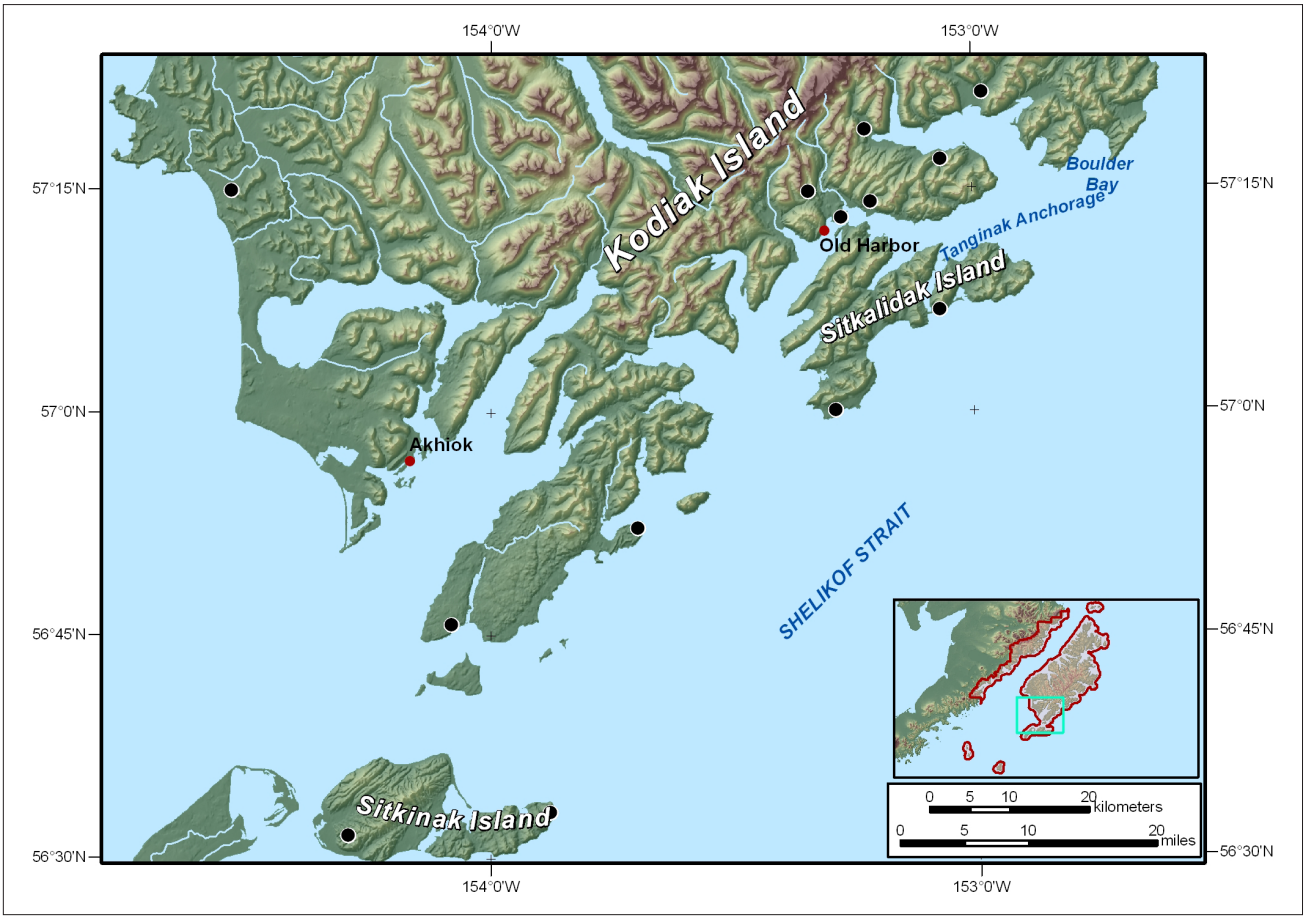


Figure F2. Location map of the southwestern Kodiak Energy Region, showing selected geographic references noted in the text. Black dots mark reported coal occurrences.

abundances are offered, nor is any information given on coal quality. Related coals on Sitkinak Island are documented in higher detail in four reports and several correspondences (Jasper and Robinson, 1959; Warfield, 1962; Anderson, 1969; Nilsen and Moore, 1979), although the earliest report significantly conflicts with the later reports in terms of coal thicknesses in the area. Jasper and Robinson (1959, and included correspondence) discuss two steeply-dipping coal beds 25 and 90 feet thick that were not observed by later workers despite efforts to locate the beds. Subsequent reports agree that coal beds on Sitkinak Island are typically thin, often impure, and laterally discontinuous (Warfield, 1962; Anderson, 1969; Nilsen and Moore, 1979). The coal that is present, however, is subbituminous A with as-received heating values of about 11,500 Btu. Other isolated coal occurrences of unknown extent in the Kodiak Energy Region are found on the upper Alaska Peninsula to the northeast (figs. F3 and F4), across the Shelikof Strait near Puale Bay and Cape Douglas (lignite), and Amalik Bay (bituminous) (Stone, 1905; Merritt and Hawley, 1986).

## Conventional oil and gas resource potential

As explained in the discussion of requirements for exploitable oil and gas resources (Chapter A), functioning petroleum systems occur in thick, sedimentary basins, and require three basic elements: Effective source rocks, reservoirs, and traps. Each of the elements must be in existence and connected at the time hydrocarbons are generated. This section provides an overview of the various basins in the Kodiak region, then considers each of the necessary elements of petroleum systems in turn to evaluate the role conventional oil and gas resources may play in supplying rural energy to the region.

***Overview of sedimentary basins.*** Onshore areas of the Kodiak archipelago are underlain primarily by Mesozoic to early Cenozoic (Paleogene) rocks, including large areas of pervasively deformed and metamorphosed deep marine deposits, strongly deformed shallow marine deposits, and more restricted granitic intrusive bodies (Lyle and others, 1978; Fischer and others, 1984; Fischer, 1988; Kirschner, 1988; Beikman, 1980). These Eocene and older rocks are thermally overmature for hydrocarbon generation, have minimal porosity and permeability, and constitute basement,

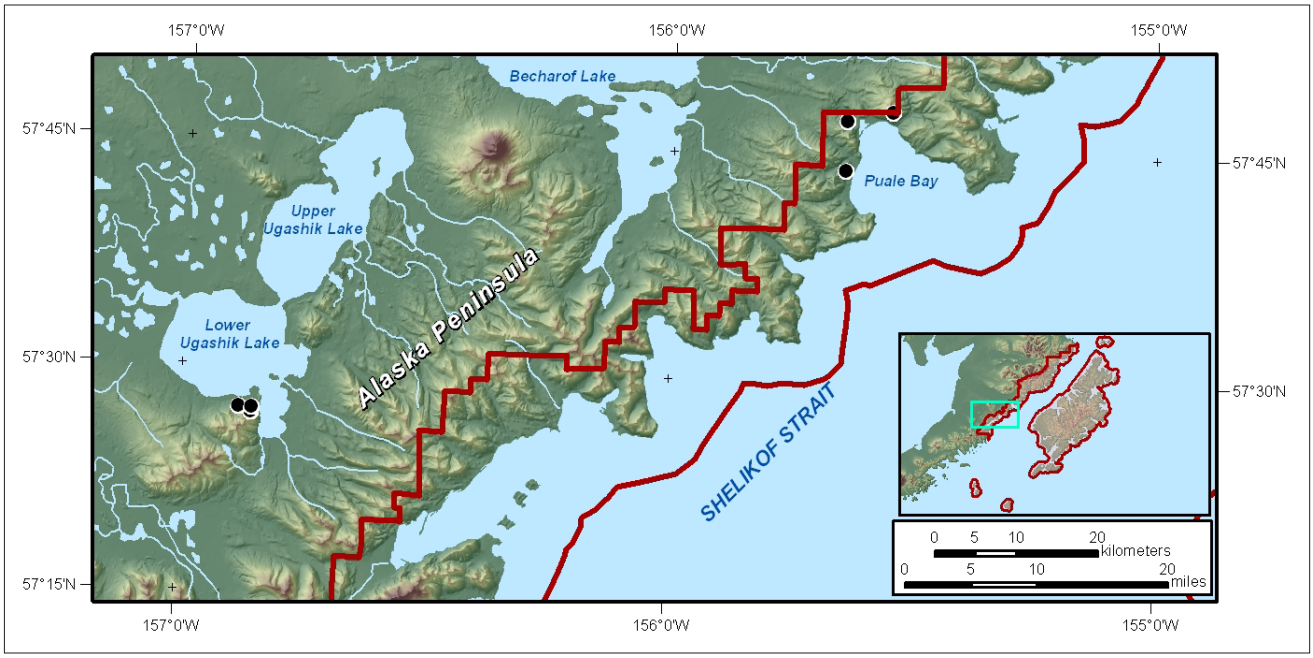


Figure F3. Location map of the western, mainland portion of the Kodiak Energy Region (Alaska Peninsula). Black dots in the Puale Bay and Lower Ugashik Lake areas indicate reported coal occurrences.



incapable of sustaining functioning petroleum systems. Less deformed late Cenozoic (Neogene) sandstone and siltstone are exposed very locally on the southeastern shore of Kodiak Island and on islands at the south end of the archipelago (Lyle and others, 1978; Marincovich, 1990). This Neogene sedimentary sequence thickens appreciably offshore into the Tugidak, Trinity, Albatross, and Stevenson basins of the Kodiak shelf (sheet 2). These shelf basins are tens to hundreds of kilometers offshore and contain 3–7 km of relatively undeformed Miocene and younger sedimentary fill (Fisher and others, 1984; Kirschner, 1988). Seismic basement beneath these Neogene basins is believed to be mainly Eocene and older rocks similar to non-prospective rocks of similar age onshore (Von Huene and others, 1980; Fisher, 1988). Six continental offshore stratigraphic test (COST) wells were drilled on the Kodiak shelf in 1976 and 1977 to acquire data in preparation for a possible lease sale that never occurred (Turner and others, 1987).

Northwest of the Kodiak archipelago, Shelikof Strait is a relatively shallow southern extension of Cook Inlet basin (sheet 2). Containing up to approximately 2 kilometers of Cenozoic strata (Magoon and others, 1979; Kirschner, 1988), this narrow basin lacks the thicker depocenters found outboard of the islands on the Kodiak shelf. However, seismic data indicate that Cenozoic strata of Shelikof Strait unconformably overlie the Mesozoic formations that host oil and gas seeps on the southeastern end of the Alaska Peninsula and source the oil in Cenozoic reservoirs in upper Cook Inlet (Magoon and others, 1979; Magoon, 1986).

***Source rocks.*** The Neogene sequence that fills the offshore Kodiak shelf basins contains organically lean shales and other non-source rock types; few intervals are known to exceed 0.5 percent total organic carbon (Fisher and others, 1984; Fisher, 1988). There is a greater chance of sourcing hydrocarbons from the underlying Eocene strata, but even these are only marginally carbon rich(<0.6 percent total organic carbon), contain only gas-prone terrestrial kerogen, and are thermally immature to marginally mature where they have been penetrated by wells (Horowitz and others, 1998). This potential source interval may be more thermally mature if it exists beneath thick Neogene depocenters. Gas shows were described from one of the six COST wells, but there is no indication that these shows represented a producible gas accumulation.

It is probable that source rocks of the Middle Jurassic Tuxedni Group (source of oil in Cook Inlet) or the partially equivalent Kialagvik Formation exist and are thermally mature beneath much of Shelikof Strait (Magoon and others, 1979; Bruns, 1982). If so, hydrocarbons generated in these units would likely migrate up to and across the unconformity at the base of Cenozoic strata, where they may or may not have encountered shallowly-buried reservoirs. The only well drilled offshore in Shelikof Strait (OCS Y-0248-1/1A) encountered minor shows of dry, possibly biogenic, gas associated with coals in the Cenozoic section, and trace amounts of probable thermogenic hydrocarbons in Mesozoic rocks.

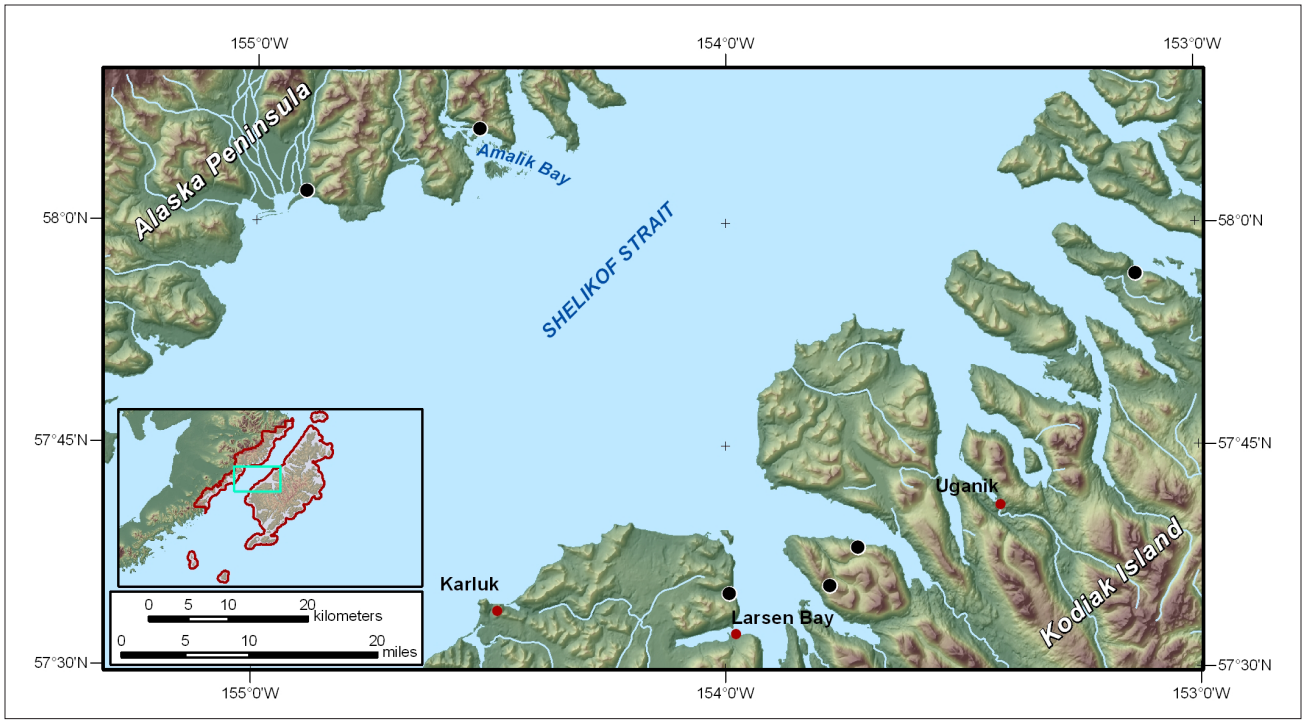


Figure F4. Location map of the Shelikof Strait area of the Kodiak Energy Region (Alaska Peninsula). Black dots mark reported coal occurrences.

***Reservoir rocks.*** Potential reservoir units in the offshore Neogene basins of the Kodiak shelf consist of marine shelf turbidite sandstones. These sandstones are mostly Middle Miocene age, more quartz-rich than older Cenozoic sandstones, and have low to moderate reservoir quality (Horowitz and others, 1998; MMS, 2006a,b). Cenozoic sandstones in Shelikof Strait are similar in many respects to age-equivalent reservoir formations of the lower and upper Cook Inlet. However, their shallow depth in much of Shelikof Strait is a practical concern (Bruns, 1982) as it could imply ineffective seals and low reservoir pressures. The OCS Y-0248-1/1A well encountered the base of the sandy Cenozoic section at a depth of only 2,619 feet below sea level in Shelikof Strait, underlain by dominantly fine-grained Mesozoic rocks. Although the reservoir potential of the Mesozoic section is unknown, it likely includes thick Jurassic sandstone and some limestone that, where favorably altered, could serve as hydrocarbon reservoirs. Limited outcrop data from correlative units in lower Cook Inlet and the Alaska Peninsula have not identified significant porosity or permeability in Jurassic rocks (Helmold and others, 2008, 2011).

***Traps.*** Numerous structural traps are mappable from seismic data offshore on the Kodiak shelf and in Shelikof Strait (Hoose and Whitney, 1980; Fisher and others, 1984; Fisher, 1993). The most prospective of these structures are anticlines related to thrust faults and normal faults (Horowitz and others, 1998) that coexist in this high-relief continental shelf prism adjacent to the Aleutian trench subduction zone.

***Summary of conventional oil and gas resource potential.*** Currently available data suggest the chance is low that recoverable oil resources are accessible either onshore or offshore in the Kodiak Energy Region. However, the data are very limited and the identification of significant Jurassic or even Triassic oil-prone source rocks would significantly improve the prospects for this area. There is an estimated 40 percent chance (Horowitz and others, 1998) that technically recoverable gas exists beneath the federally managed waters of the Kodiak shelf offshore of the Kodiak Energy Region. The most recent federal assessment (MMS, 2006a,b) estimates the mean undiscovered, technically recoverable resource at 1.8 trillion cubic feet (TCF), likely distributed as small accumulations among many different late Cenozoic reservoirs in anticlinal traps tens to hundreds of kilometers offshore.

## Unconventional oil and gas resource potential

***Coalbed methane.*** As noted above, coal resources in the Kodiak region are areally limited, discontinuous, and of uncertain thickness (Nilsen and Moore, 1979). There is very little in the public record documenting the nature of coals on Kodiak and surrounding islands. Available data on the thickness of these coals, combined with uncertain areal footprint, suggests they would be ineffective as potential sources of coalbed methane.

***Tight gas sands.*** The bulk of the sandstones in the Neogene basins of the Kodiak shelf are too young and too shallowly buried to be effective tight gas reservoirs. Despite the low to moderate reservoir quality of these sandstones, they do not exhibit a well-developed regional fracture system conducive to the genesis of tight gas sands. Given this fact, combined with available data suggesting only lean source rocks in the region, the likelihood of tight gas sands in the Cenozoic section is low. The thickness and character of Jurassic units beneath the Shelikof Straight are poorly known. If the stratigraphy is comparable to lower Cook Inlet and parts of the Alaska Peninsula, then well-lithified units may potentially have reservoir quality consistent with a tight gas play.

***Shale gas.*** The bulk of potential Neogene source rocks in the Kodiak shelf basins are lean in organic matter and probably not capable of producing sufficient quantities of gas to support a shale gas resource play.

***Gas hydrates.*** The main occurrences of gas hydrates in nature are in modern marine sediments and in arctic regions with well-developed, continuous permafrost. Permafrost is not well developed in the Kodiak Energy Region and, where locally present, is discontinuous. Consequently, the potential for economic concentrations of gas hydrates is low.

### Geothermal resource potential

There are no known occurrences of thermal springs, fumaroles, warm lakes, or mud pots in the Kodiak Energy Region and the overall geothermal prospectivity in the area is low. The current understanding of the regional geology suggests that discovery of a developable geothermal system is unlikely, with the exception of the westernmost part of the region, which borders several fumaroles in the Katmai area (see Bristol Bay Energy Region, Chapter D).

## RECOMMENDATIONS

### Coal resource recommendations

Given the restricted distribution and thinness of coal beds that have been observed by most researchers, further investigation of coal resources in the Kodiak Island area are unwarranted. Additionally, Sitkinak and Sikalidak islands are part of the Alaska Maritime Wildlife Refuge, which would complicate any plans to develop a resource at those locations. Reconnaissance-level mapping of reported coal occurrences on the Alaska Peninsula may help determine if further investigation into coal resources is warranted. However, these sites are with the Katmai National Park and Preserve and Becharof National Wildlife Refuge, and thus may not be accessible for coal-resource development.

### Conventional oil and gas resource recommendations

The oil potential in the Shelikof Strait is poorly constrained, but generally assumed to be limited. Technically recoverable gas resources may be present offshore on the Kodiak shelf or in Shelikof Strait. However, these areas have seen limited drilling, and there has been no petroleum industry interest in the region for 25 years. The onshore areas host no active petroleum system. Although industry may eventually pursue offshore exploration, conventional hydrocarbons are unlikely to fulfill local energy needs in the near future.

### Unconventional oil and gas resource recommendations

***Coalbed methane.*** Due to the limited stratigraphic and areal extent of coals in the region, the volume of available coal is not sufficient to produce commercial quantities of coalbed methane, and no further action is recommended.

***Tight gas sands.*** The possibility of encountering fractured tight gas sands in the Kodiak Energy Region is low due to the young age and shallow burial of Cenozoic reservoirs. Little is known regarding possible Mesozoic tight gas reservoirs. Characterizing potential Mesozoic reservoirs would require expensive drilling in the Shelikof Strait area and such an investment is not recommended.

***Shale gas.*** Due to the lack of extensively fractured source rocks in the thermogenic gas window, the likelihood of finding commercial quantities of shale gas in the region is low; therefore no further action is recommended.

***Gas hydrates.*** Due to the lack of extensive, continuous permafrost on Kodiak and surrounding islands, the likelihood of finding gas hydrates in the region are very low; therefore no further action is recommended.

### Geothermal resource recommendations

Due to the lack of documented geothermal manifestations, the potential for developable geothermal energy in the region is low and no further action is recommended.

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