Chapter Six: Oil and Gas Exploration, Development and Production, and Transportation

Table of Contents

Page

List of Figures

Figure **Page**

List of Maps

Map **Page**

Chapter Six: Oil and Gas Exploration, Development and Production, and Transportation

A. Geology

1. Tectonic and Structural Framework

The Alaska Peninsula is part of an active region of the earth's crust. In plate tectonic terms, the Pacific Plate is being subducted under the North American plate along the Aleutian trench at an oblique angle. The magmatic arc that runs the length of the Alaska Peninsula trends toward the northeast and has been active since the Mesozoic era. It is located between the Mesozoic-Cenozoic Cook Inlet forearc basin to the south and the Cenozoic North Aleutian/Bristol Bay backarc basin to the North. This magmatic arc contributes to a complex thermal and tectonic history. Rocks of the Alaska Peninsula range in age from the Permian to Holocene and rock structures trend predominantly northeast, below and parallel to the arc and the peninsula's long axis. Exposed rocks include both volcanic (formed from cooling lava on the surface) and plutonic rocks (formed from cooling magma below the surface), and shallow marine and continental sedimentary deposits containing mainly volcanic and plutonic debris (Vallier 1994).

Beneath much of the Alaska Peninsula is a complex layering of different sequences of rocks formed when fragments of crust break off one tectonic plate and become part of a different plate, often during subduction. This is referred to as tectonostratigraphic terrane. The Alaska Peninsula or Peninsular terrane consists of Permian to Upper Cretaceous rocks placed there through plate tectonic processes. Paleocene and younger deposits cover much of the Peninsular terrane region. These deposits become thicker towards the northwest and into the North Aleutian backarc basin.

The Peninsular terrane is a combination of two different subterranes separated by faults and roughly the same age. These are the Iliamna and Chignik subterranes (Wilson et al. 1985). Northeast of Becharof Lake, both subterranes are well exposed and clearly separated by the Bruin Bay fault. On the northwest side of the fault, the Iliamna subterrane is thrusting upwards. The exposed subterrane contains mainly plutonic, volcanic, and metamorphic rocks, including the Alaska-Aleutian Range batholith. On the southeast side, the Chignik subterrane is sinking down and contains Triassic to Cretaceous sedimentary units, including rich oil-prone source rocks, some of which are at oil-window (ready to easily expel oil) and others which are at a lower level of thermal maturity.

South of Becharof Lake, it is believed the Bruin Bay fault is covered by Tertiary extensional faults from the Ugashik Lakes fault system, supporting subsidence (sinking) of the northeast sector of the North Aleutian basin and Ugashik sub-basin (Decker 2008). Continuing southward, the commingled Bruin Bay and Ugashik Lakes fault systems are obscured by younger volcanic cover. It is unclear how much of the source-prone Chignik subterrane may lie underneath Tertiary deposits along the edge of the North Aleutian basin in the sale area.

The North Aleutian basin is oldest and deepest in the area west and north of Port Moller, where the east-west basin axis contains up to approximately 5,500 m (18,000 ft.) of Paleocene and younger sedimentary strata, or layers. Review of seismic and rock outcrop information indicates that a mix of compressed, extensional (pulling apart), and strike-slip (blocks of rock that slide past each other horizontally) structures form the southern boundary of the basin adjacent to the Black Hills uplift and the Staniukovich anticlinorium in the southwestern-most part of the sale area (Finzel et al. 2005; Decker et al. 2005; Decker 2008).

2. Previous Work and Sources of Additional Stratigraphic Information

Significant new information regarding the petroleum resource potential of the Alaska Peninsula has become available since the previous best interest finding for the Alaska Peninsula issued in 2005. This information is now available as the result of several years of integrated field and subsurface research in the Alaska Peninsula region led by DNR geologists from the Division of Geological and Geophysical Surveys (ADGGS) and the Division of Oil and Gas (DO&G). Additional technical information about the regional petroleum systems is available in DNR-published reports (e.g., Finzel et al. 2005; Decker et al. 2005; Reifenstuhl and Decker 2008 and the reports contained therein). A major biostratigraphic study of 11 onshore and offshore wells in the region was underwritten by DO&G, and is available for free download from the Division's website (Micropaleo Consultants 2005). Appendix A of this best interest finding contains descriptions of the formations referenced in the stratigraphic column for the area modified by Hite (2004) (Figure 6.1); units are described in stratigraphic order from oldest to youngest.

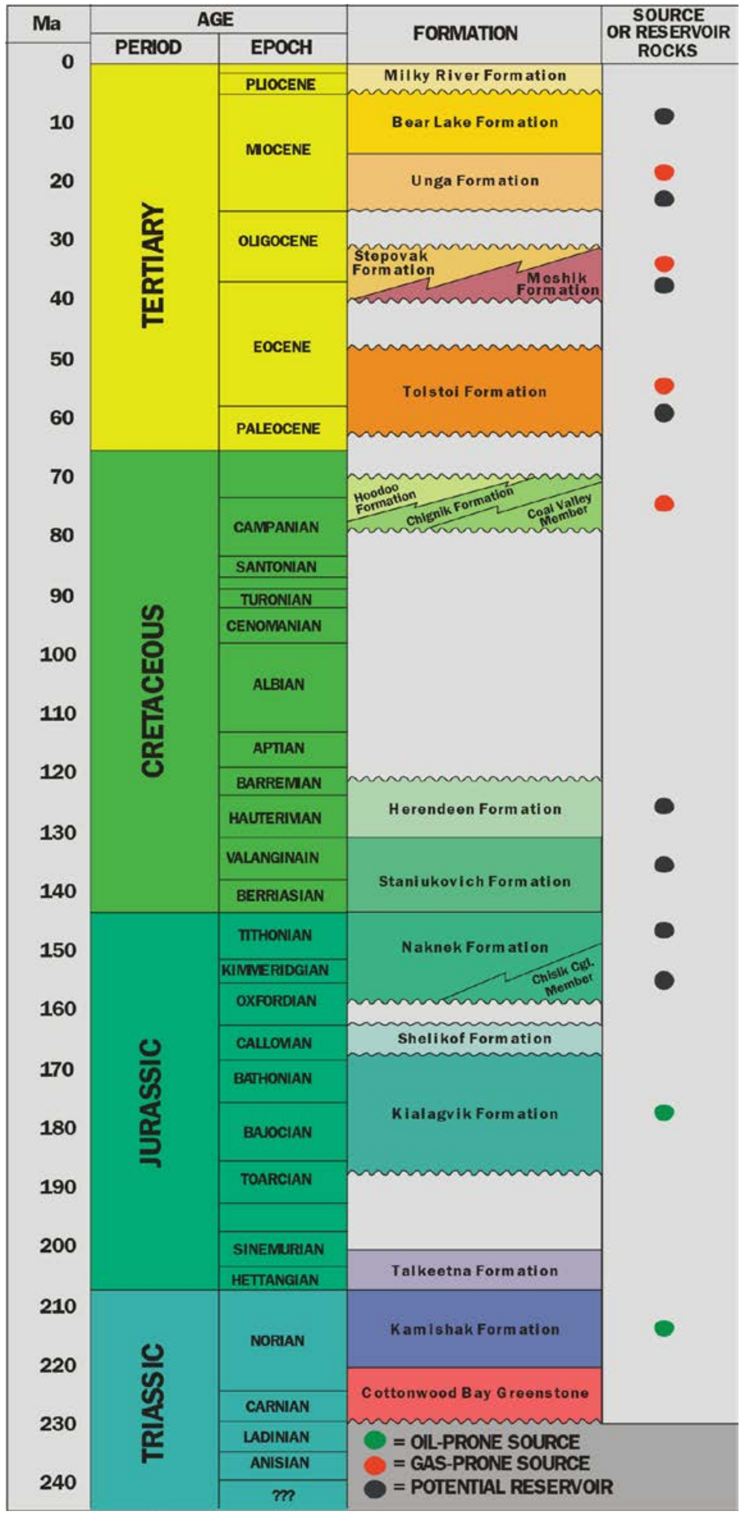


Figure 6.1 Stratigraphic Column Modified by Hite (2004)

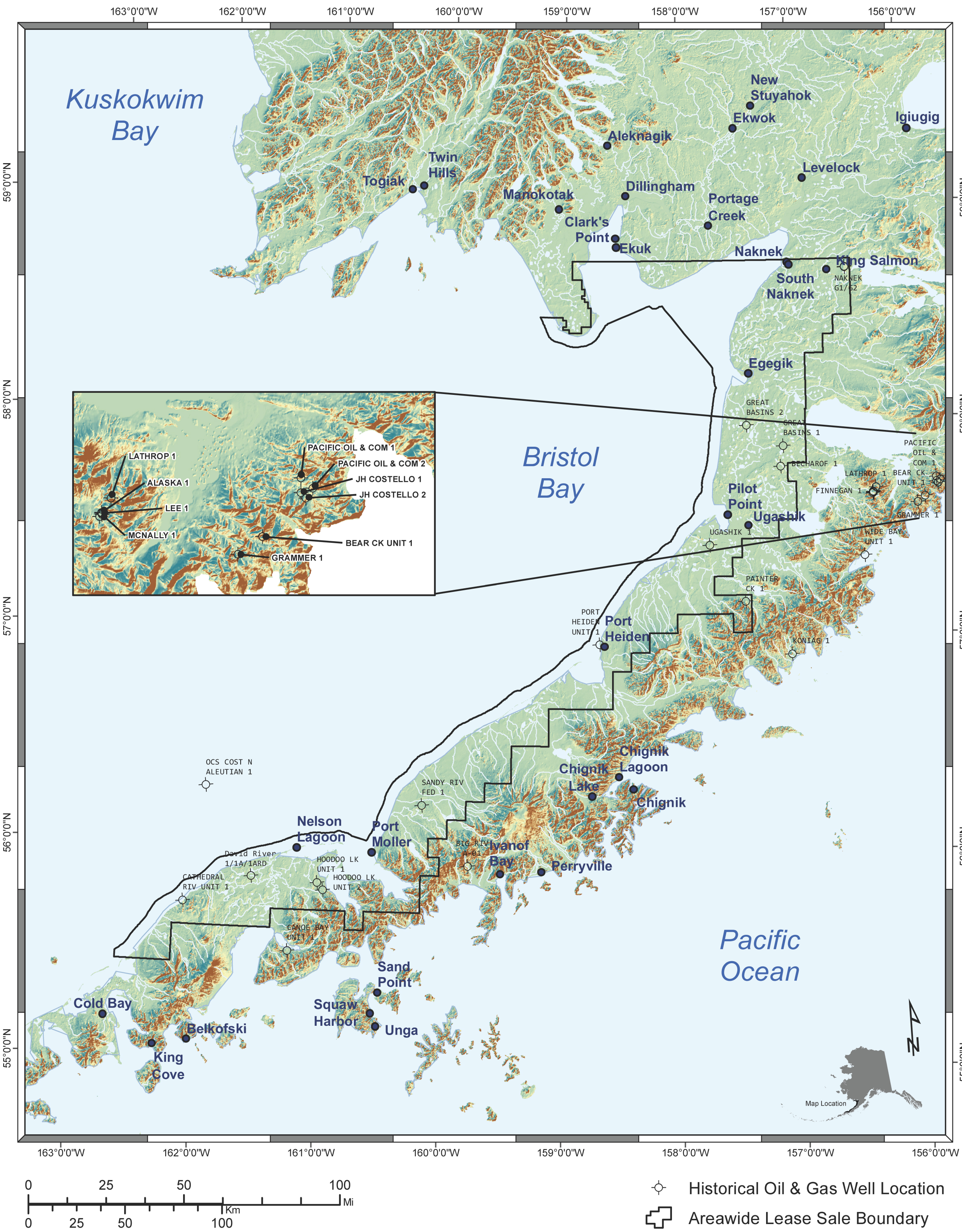
B. Exploration History

Oil and gas seeps were first discovered in the region on the Iniskin Peninsula on the west side of Cook Inlet by Russians around 1855. On the Alaska Peninsula, oil and gas seeps are mostly concentrated near the Wide Bay area on the southeastern side of the peninsula south of Becharof Lake (see Blodgett and Clautice 2005 for detailed locations and descriptions). Surface petroleum seeps in this area have been clearly linked to Mesozoic oil and gas source rocks (Magoon and Anders 1992; Decker 2008).

The Alaska Peninsula was first explored in the early 1900s and the first wells were drilled on the southeast side near active oil and gas seeps. Exploration shifted to the northwest side of the Alaska Peninsula in the late 1950s through early 1980s. Since 1902, 35 exploration wells have been drilled, 11 of which are within the boundary of the sale area. Only four wells were drilled between 1977 and 1985. The two most recent wells drilled in the region were the North Aleutian COST 1, completed in offshore Federal waters in 1983, and the Amoco Becharof 1, drilled on state acreage in 1985.

Concern, over potential damage to the prolific wild salmon fishery in Bristol Bay, halted hydrocarbon exploration throughout the area from 1985 until 2005 when the State first offered onshore and nearshore acreage for lease in the Alaska Peninsula areawide sale. In that first sale, the state received bids on 37 tracts. Shell Offshore Inc. bid on 33 tracts and Hewitt Mineral Corp. bid on four tracts. All 37 tracts leased were contiguous in the Nelson Lagoon, Herendeen Bay, and Port Moller Areas. In 2007, Hewitt Mineral Corp. acquired one tract, southwest of Herendeen Bay, adjacent to their previously leased acreage. Shell Offshore Inc. relinquished their leases on October 20, 2008 and Hewitt Minerals Corp. relinquished their leases on October 25, 2010. No other companies have bid on state acreage in the annual Alaska Peninsula areawide lease sales since 2007. To date, no development, production, or transportation has taken place.

Although nearly all the wells in the area have had at least modest shows of oil and/or gas, to date there have been no commercial oil or gas discoveries or sustained production from state lands on the peninsula (Map 6.1). While oil and gas prone source rocks are clearly present and functioning in areas containing flowing oil and gas seeps, their subsurface distribution and maturity are unknown in other areas. This creates uncertainty regarding reservoir quality, thermal maturity, and the location and integrity of both structural and stratigraphic traps. Recent industry focus appears to be on natural gas as a more likely product than oil, and industry recognizes that much of the gas potential is offshore beneath the federal waters of Bristol Bay (Decker 2006).



Map 6.1 Historical Well Locations In and Near the Alaska Peninsula Sale Area

Based on very little data, the U.S. Geological Survey (USGS) estimated mean undiscovered, technically recoverable onshore Alaska Peninsula resources very conservatively, at 9 MMSTB (million stock tank barrels) of oil and 188 BCF (billion cubic feet) of gas (USGS 1996). That assessment assigned a 32% chance (0.32 marginal probability) that the area is capable of producing at least one technically recoverable accumulation. The term 'technically recoverable' does not consider economic factors related to the cost of drilling or producing hydrocarbons. Having participated in field and subsurface petroleum systems research in the region, DO&G staff are of the opinion that future resource assessments, if informed by a robust, regionally extensive grid of modern seismic data, would likely result in much higher estimates of undiscovered oil and gas.

C. Oil and Gas Potential

Appendix A contains detailed information regarding source rock, reservoir, and trap potential. Below are the overview and conclusions regarding oil and gas potential in the Alaska Peninsula sale area.

1. Overview of the Petroleum Systems Approach

The basic elements of a functional petroleum system are effective sources, reservoirs, and traps. The presence of these three elements by themselves does not ensure that a viable hydrocarbon system will be present. The elements must also interact with each other properly to create oil or gas accumulations.

Source rocks contain kerogen, organic material that is predominantly composed of carbon and hydrogen, the main ingredients in oil and gas. In order to form oil or gas, a source rock must be buried deep enough and long enough in an area of the basin that geochemists refer to as the "kitchen", where the proper range of temperature and pressure converts kerogen into hydrocarbons. Generation of the oil or gas in the source rock creates excess pressure which expels hydrocarbons out of the source rock. At that point, because it is lighter than and does not mix with the water saturating the surrounding rock, it tends to migrate upward, either directly or along a more indirect route, following the most permeable pathways it encounters.

A reservoir rock is a porous and permeable rock (typically sandstone or a carbonate rock type such as limestone or dolomite) that can effectively store oil or gas. Less permeable rocks are sometimes suitable reservoirs for gas or lighter oil, since those fluids flow more easily than normal or heavy crude oil. An important consideration for assessing potential reservoir rocks in the Alaska Peninsula are the composition and diagenesis (chemical alteration) of the volcanic rock fragments that comprise a significant percentage of framework grains in many of the sandstones in the area. Formations buried less deeply are more likely to have better preserved primary porosity.

The reservoir rock must be contained in a sealing configuration called a trap, which allows hydrocarbons to migrate into the reservoir, but prevents it from escaping, thereby creating an oil or gas accumulation. Effective containment inside the trapping configuration requires an effective seal, generally a clay or mudstone layer that forms an impermeable barrier at the top of the trap that prevents hydrocarbons from escaping.

Conventional trapping configurations are generally either structural or stratigraphic. Structural traps are formed by deformation of originally flat-lying, planar strata to create either anticlines (up-warped layers) or fault-bounded compartments, forming large concave-down shapes that allow buoyant oil or gas to migrate upward and accumulate. Stratigraphic traps result when porous and permeable reservoir rock is bounded both above and to the side(s) by impermeable seal rocks, simply due to the way the different sediment types were deposited. There are also traps that are a combination of structural and stratigraphic configurations. Effective traps must be created prior to hydrocarbon generation, expulsion, and migration from the kitchen and remain intact, uncompromised by later folding, faulting, or excessive burial in order to host a productive oil or gas field (Decker 2006).

Further subsurface work is required to determine whether all three of the critical petroleum system elements (source rocks, reservoirs, and traps) are present, effective, and have interacted with favorable timing to form viable hydrocarbon traps in the Alaska Peninsula sale area. The area remains dramatically underexplored for oil and gas, and the question can only be answered through additional exploration drilling of prospects mapped using modern, high-quality 2-D and/or 3-D seismic surveys. The remote location of the Alaska Peninsula presents logistical and economic challenges for exploration and development operations.

2. Conclusions

Recent work by DNR geologists demonstrates that the Alaska Peninsula sale area likely contains all the essential elements of petroleum systems (effective hydrocarbon sources, reservoirs, and traps) and offers reasonable hydrocarbon potential. There is uncertainty about the timely combination of petroleum system elements to create major economic hydrocarbon accumulations, but concerted exploration would likely discover recoverable hydrocarbons in Tertiary reservoirs, and potentially in some Mesozoic units. Some of the challenges are due to the tectonic setting, provenance, depositional and burial history, and diagenesis of the area. Limitations in data availability (the lack of regional onshore seismic surveys and sparse well control) pose significant challenges to defining drillable prospects.

Though past exploration has not yielded commercial production, there are indications that the necessary components of active petroleum systems may be present in both Mesozoic and Cenozoic sequences. Source presence and effectiveness are demonstrated by the presence of significant oil and heat producing gas seeps in Mesozoic units, and by subsurface thermogenic (generated by heat) and biogenic (generated by bacteria) gas shows in Tertiary units in wells. Mesozoic sandstones are degraded by zeolites, but may function as tight-gas reservoirs, particularly in the presence of favorable fracture systems, and the carbonates of the Triassic Kamishak Formation may locally develop reservoir quality. Reservoir presence and effectiveness is much more promising in Tertiary formations, in particular the Miocene Bear Lake Formation, as confirmed by classification and porosity permeability analyses of outcrop and well samples. The area’s complex stratigraphic and structural history suggests that structural and unconformity-related stratigraphic trapping configurations are likely present. Seal capacity studies demonstrate that both Mesozoic and Cenozoic formations could contain significant hydrocarbon columns (Reifenstuhl 2008).

D. Stages of Oil and Gas Resource Development

The entire process of locating oil and gas and bringing it to market can be separated into stages: exploration, development and production, and transportation. These stages may occur simultaneously on any part of the lease or unit. Whether exploration and eventual development will occur in the sale area depends on several factors, such as the subsurface geology of the area, a company's worldwide exploration strategy, the projected price of oil and gas and their market demand, and other economic, environmental and logistical factors. Geology dictates the extent of exploration. Several dry holes (drilling that results in no substantial hydrocarbons encountered) can discourage further exploration in an area. Whether a lessee proceeds with exploration of an area may depend on the area's priority when weighed against the lessee's other worldwide commitments. If extensive exploration does occur in an area, and an accumulation is discovered, development and production will only proceed if the lessee finds the risks acceptable, given the potential costs. This depends on the price of oil and gas, the lessee's development costs, and the cost of getting the oil and gas to market. As stated above, the remote location of the Alaska Peninsula presents logistical and economic challenges for exploration and development operations.

1. Disposal

Oil and gas lease sales are a first step in developing the state's oil and gas resources. Annually, DO&G prepares and presents a 5-year program of oil and gas lease sales to the legislature. DO&G also conducts annual competitive areawide lease sales, offering for lease all available state acreage within five areas. A lease sale area is divided into tracts, and interested parties that qualify may bid on one or more tracts.

Although beyond the scope of this best interest finding, exploration licensing supplements the state's areawide oil and gas leasing program by targeting areas outside of known oil and gas provinces. The intent of licensing is to encourage exploration in areas far from existing infrastructure, with relatively low or unknown hydrocarbon potential, where there is a higher investment risk to the operator. Because bonus payments are required to win a lease, lease sales held in some of these higher-risk areas tend to attract little participation. Exploration licensing gives an interested party the exclusive right to conduct oil and gas exploration without this initial expense. Through exploration licensing, the state receives valuable subsurface geologic information on these regions and, should development occur, additional revenue through royalties and taxes (AS 38.05.131-134).

2. Exploration

Oil and gas resource exploration begins with gathering information about the petroleum potential of an area by examining surface geology, researching data from existing wells, performing environmental assessments, conducting geophysical surveys, and drilling exploratory wells. The surface analysis includes the study of surface topography or the natural surface features, and near-surface structures revealed by examining and mapping nearby exposed rock layers. Geophysical surveys, primarily seismic, help reveal the characteristics of the subsurface geology. Geophysical exploration and exploration drilling are likely activities that could result in potential effects to the sale area.

Seismic exploration and related activities do not require a disposal decision, lease, or approval of the exploration phase, but do require the appropriate authorizations. For example, seismic exploration would require a land use permit issued by DNR. Exploration can also happen at any time. Activities associated with exploration can occur simultaneously, before, after, or even during disposal and development and production. Exploratory drilling, on the other hand, would occur after disposal and require a plan of operations and DO&G approval before a lessee began any on-the-ground work. In the meantime, other operations such as production activities may have already been approved and may be occurring on another part of the lease or unit.

a. Geophysical Exploration

Seismic surveys are the most common type of geophysical exploration. Energy is emitted at the survey location into the subsurface and reflected seismic waves are recorded at the surface geophones and/or hydrophones (vibration-sensitive devices). Different rock layers beneath the surface have different velocities and densities. This results in a unique seismic profile that can be analyzed by geophysicists to interpret subsurface structures and petroleum potential. Advancements in seismic sensors and recording systems technology have resulted in higher definition and greater productivity. In addition, it is anticipated this will create greater efficiency in exploration with fewer effects on the environment (New Developments in Upstream Oil and Gas Technologies 2011).

Additional geophysical techniques can be used to gather information specifically about very near surface geology, usually to identify drilling hazards. They include high-resolution shallow seismic, side-scan sonar, fathometer recordings and shallow coring programs. High-resolution shallow seismic surveys are specifically designed to image the bottom of a water body and very shallow geology. They employ a lower energy seismic source and a shorter cable than surveys targeting deeper oil and gas potential.

b. Drilling Exploration

Exploratory drilling often occurs after seismic surveys are conducted, and review of the seismic and geologic data indicates possible oil and gas prospects. Drilling is the only way to learn whether a prospect contains commercial quantities of oil or gas, and helps determine whether to proceed with development. Drilling operations collect well logs, core samples, cuttings, and a variety of other data. A well log is compiled by lowering measuring instruments in a well bore and taking measurements at various depths. Well logs can also be recorded while drilling. Cores may be cut at various intervals so that geologists and engineers can examine the sequences of rock that are being drilled.

One way to take readings is through Measurements While Drilling (MWD) technology. Tools at the end of the drilling apparatus may include gyroscopes, magnetometers, and accelerometers. These provide real-time drilling information such as wellbore position, drillbit information, directional data, and borehole inclination and azimuth during drilling. These data are transmitted to the surface through pulses through the mud column and electromagnetic telemetry. Data are decoded at the surface and transmitted to an offsite location. This allows drilling engineers to make important decisions while drilling (Rigzone 2013).

3. Development and Production

During development, operators evaluate exploratory drilling results and develop plans to bring the discovery into production. Production operations bring well fluids to the surface and prepare them for transport to the processing plant or refinery. The fluids undergo operations to purify, measure, test and transport. Pumping, storage, handling, and processing are typical production processes (Van Dyke 1997). The final project parameters will depend on the surface location, size, depth, and geology of a specific commercial discovery.

After exploration wells have been drilled, a process called extended reach drilling (ERD) may be used during production. ERD can be used for both onshore and offshore reservoirs. ERD is already being used in Prudhoe Bay, Alaska to access offshore reservoirs using drilling rigs from land (New Developments in Upstream Oil and Gas Technologies 2011). ERD not only reduces wellsite footprints and minimizes environmental effects, but also improves reservoir drainage at the least cost (Schlumberger 2013).

Production facilities contain oil and gas production equipment located within their boundaries (EPA 2011). On the well site, these may include processing facilities to remove some of the water produced with the petroleum, water and sewage treatment equipment, power generators, drilling rigs, and support buildings and housing for workers. Support facilities may include a production facility to receive and treat or transport the oil and gas to markets, refineries, or shipment to other processing facilities located in the lower 48 states and elsewhere. Other support facilities may include a supply base and transportation system for cement, mud, water, food, and other necessary items.

4. Subsurface Oil and Gas Storage

Under AS 38.05.180(u), the Commissioner of DNR may authorize the subsurface storage of oil or gas to avoid waste or to promote conservation of natural resources. In Alaska, depleted reservoirs with established well control data are preferred storage zones. By memorandum dated September 2, 2004, the Commissioner approved a supplement to Department Order 003 and delegated the authority to authorize subsurface storage of oil or gas to the Division of Oil and Gas Director.

Subsurface storage of gas increases reliability of gas delivery to all sources of demand. The need for gas storage also depends upon access to transportation, pipeline infrastructure, existing production infrastructure, gas production sources, and delivery points. A subsurface storage authorization allows the storage of gas and associated substances in the portions of the gas storage formation, subject to the terms and applicable statutes and regulations, including mitigation measures and advisories incorporated by reference into the authorization. It does not matter whether the oil or gas is produced from state land, so long as storage occurs in land leased or subject to lease under AS 38.05.180.

5. Transportation

Transportation is also a phase of oil and gas resource development. See the next section for further discussion.

E. Likely Methods of Oil and Gas Transportation

AS 38.05.035(g)(1)(B)(viii) requires the director to consider and discuss the method or methods most likely to be used to transport oil or gas from the sale area, and the advantages, disadvantages and relative risks of each. Any oil or gas ultimately produced from leases will have to be transported to market. It is important to note the decision to lease oil and gas resources in the state does not authorize the transportation of any oil or gas. If and when oil or gas is found in commercial quantities and production is proposed, final decisions on transporting will be made through the local, state, and federal permitting process.

No oil or gas will be transported from the sale area until the lessee has obtained the necessary permits and authorizations from federal, state, and local governments. The state has broad authority to withhold, restrict, and condition its approval of transportation facilities. In addition, the federal and local governments may have jurisdiction over various aspects of any transportation alternative.

Modern oil and gas transportation systems may consist of pipelines, marine terminals with offshore loading platforms, trucks, and tank vessels. The location and nature of oil or gas deposits determine the type and extent of facilities needed to develop and transport the resource. Due to the limited road system in the sale area, the most likely method of transportation will include pipelines, marine terminals and tanker vessels. Currently, truck transportation is not an option although its possibility is discussed below. A general overview of the likely transportation methods is discussed below.

1. Pipelines

One method of transporting oil is by pipeline. Pipelines may be onshore or offshore. Onshore pipelines may be buried or unburied. Buried pipelines, over which the ground is normally reseeded, are advantageous because they do not pose an obstacle to wildlife or result in scenic degradation. However, buried pipelines are more expensive to install and to maintain than unburied pipelines. This is especially true in regards to inspection, repair and maintenance (SPCO 2011). Spills may result from pipeline leaks in either buried or unburied pipelines, and leak detection systems play a primary role in reducing discharges of oil from either system. Elevated pipelines offer more ways to monitor the pipeline such as ground inspection, visual air inspections, ground-based infrared (IR) and airborne forward-looking infrared (FLIR) surveys. In-Line Inspection (ILI) can be used for both aboveground and belowground crossings, but is the only practical method for belowground installations (SPCO 2011).

Offshore pipelines usually do not hinder water circulation and minimally affect fish and wildlife habitat. Weighted pipelines are used in areas where tidal currents are exceptionally strong. Marine arctic pipelines are usually trenched and buried (C-CORE 2008). This technique is advantageous because it may offer a way to avoid creating a navigational hazard or being damaged by ship anchors, by sea ice, or by trapping fishing nets. In deeper water, weighted pipelines may be disadvantageous because they may become silted-in or self-buried. A disadvantage of sub-sea pipelines is that they are expensive to build and maintain. They can be difficult to monitor for leaks, defects, and corrosion problems, however significant advances have been made in recent years.

Sophisticated monitoring methods now available can overcome many disadvantages of subsea pipelines. Some of these include:

- volumetric flow measurement;
- pressure monitoring;
- pressure measurement with computational analysis;
- external oil detection;
- remote sensing;
- geophysical sensing techniques;
- pressure or proof testing;
- pipe integrity checking (i.e., smart pigging);
- visual inspection; and
- through-ice borehole sampling.

Many of these methods are considered to be proven technology while others are still under development (C-CORE 2008).

2. Marine Terminals

If oil or gas must be transported across marine waters by tanker, a marine terminal is necessary. Crude oil terminal facilities generally store quantities of oil equivalent to several large tanker loads. Therefore, a disadvantage of transporting oil or gas by tanker is the possibility for a very large spill at these facilities. A strong earthquake or other natural disaster could damage the facilities and initiate a large spill. The risk of explosion or sabotage at the facilities also exists. Accidental ballast discharge or loading or unloading accidents could also cause a spill. However, environmental risks have been minimized through improved design, construction, operating techniques and spill prevention measures.

The fixed location of loading facilities at marine terminals improves spill response and contingency planning. With constant staffing, leaks are easier to detect than with some pipelines. For example, the Valdez Marine Terminal is staffed 24 hours a day and its oil response crews are trained to conduct land and water response operations. Even though a spill from a tanker is the responsibility of the tanker owner, Alyeska Pipeline Service Company provides initial response. Spill prevention measures include (APSC 2011):

- training;
- extensive inspection programs;
- monitoring of transfer operations;
- facility security programs;
- use of proper valves and overfill alarms;
- secondary and tertiary containment systems around the tanks; and
- drug and alcohol testing of personnel.

3. Tank Vessels

Deep water ports are required for tanker operations; it is therefore anticipated that any future tanker operations associated with the Alaska Peninsula would be located on the south side of the peninsula (MOU 2003a; USFWS 1985, 1988). The biggest disadvantage for tankers is the potential for a large oil spill, although in recent years spills from pipelines outnumber those from tankers (Etkin 2009). More recently, data indicate tanker spillage continues to decline despite an overall increase in oil trading (ITOPF 2012; Anderson et al. 2012).

Tankers are also used to transport natural gas. Liquefied natural gas (LNG) is methane that has been cooled to an extremely cold temperature (-260° F/ -162.2° C), where it becomes liquid. At standard atmospheric conditions, methane is a vapor. LNG is stored and transported exclusively at cryogenic temperatures, so it is maintained in a liquid state, facilitating storage and transportation. LNG should not be confused with NGL (Natural Gas liquid) or LPG (liquefied petroleum gas), which are transported at near ambient temperature.

4. Trucks

Transporting oil and gas by pipeline is safer than trucks on roadways when measured by incidents, injuries, and fatalities (Furchtgott-Roth 2013). Between 2011 and 2012 trucks moving oil to refineries within the United States and Canada has increased by 38% (IER 2013). The road system in the sale area is very limited. The Southwest Alaska Transportation Plan (SWATP) addresses the various transportation needs for communities in and around the sale area. In particular is the Cook Inlet to Bristol Bay corridor. A narrow existing road between Williamsport and Pile Bay has not been adequately maintained and several bridges need upgrading. Before this corridor can be completed, several individual smaller projects must be completed first. According to the SWATP, only three northern segments of the six proposed segments in this corridor are likely to be constructed in the next 10 years. They have most engineering and environmental documentation completed while the other segments are conceptual (DOT&PF 2004).

In part, due to changing levels of state and federal funding for transportation improvements, the SWATP is being updated. It includes a public involvement process, and is expected to be developed over a two-year period. Phase I of the planning project focuses on gathering information and identifying key issues and needs to be addressed in the transportation plan. Phase II's focus will be on evaluating various transportation system improvements to resolve issues or meet needs identified in Phase I. Overall, the plan will evaluate the best way to invest public infrastructure spending in Southwest Alaska (DOT&PF 2011). Further review of the DOT&PF website, SWATP, and SWATP update indicates the Cook Inlet to Bristol Bay corridor is being reevaluated and depending upon funding and need, may not be completed for many years (DOT&PF 2014).

The federal government is the major source for transportation funding in Alaska. DOTPF is responsible for prioritizing, arranging, and administering the majority of capital projects. The State of Alaska pays for maintenance and operations for State roadways, but does not dedicate revenue to transportation purposes. The Alaska legislature maintains a large degree of control over State transportation programs and priorities. DOTPF projects and programs must compete each year with other social and infrastructure needs for money from the General Fund (DOT&PF 2004).

5. Summary

The mode of transportation from a discovery will be an important factor in determining whether or not a discovery can be economically produced. The more expensive a given transportation option, the larger a discovery will have to be for economic viability. Oil and gas produced from the sale area would likely be transported by a system of gathering lines, processing facilities, marine terminal, and tankers. Because there has been no oil or gas production on the Alaska Peninsula to date, a transportation system of wells, gathering lines, processing facilities, terminals, other infrastructure, and tankers would have to be constructed. If resources are discovered and developed, more detailed transportation options, such as exact routes, locations, and size of facilities, would need to be evaluated.

F. Oil Spill Risk, Prevention, and Response

1. Introduction

AS 38.05.035(g)(1)(B)(vii) requires the director to consider and discuss lease stipulations and mitigation measures, including any measures to prevent and mitigate releases of oil and hazardous substances, to be included in the leases, and a discussion of the protections offered by these measures. The mitigation measures related to release of oil and hazardous substances were developed after the director considered the risk of oil spills, methods for preventing spills, and techniques for responding to spills. The director also weighed whether it was in the state's best interest to hold lease sales on the Alaska Peninsula. Mitigation measures can be found in Chapter Nine.

For most of the last 40 years or so, oil spill rates in U.S. waters have decreased as a result of prevention oriented regulations and voluntary industry initiatives. As of 2007, U.S. pipelines spilled considerably more than tankers and barges. Also, as of 2007 over nine times as much oil was released from natural seeps as was spilled from all sources, and spills attributable to public consumers input more oil into U.S. waterways annually than the Exxon Valdez oil spill did (Etkin 2001, 2009).

The largest offshore spills also decreased in size from 1964 through early 2010, a period of over 45 years. In 2010, improvements in the spill record were broken by the Macondo spill in the Gulf of Mexico. When calculating the spill volume for all offshore spills, the Macondo spill size overwhelmed the rest of the record. Its volume was more than 8.5 times the cumulative that had been spilled in the previous 46 years (Anderson et al. 2012).

From 1996-2010, Outer Continental Shelf (OCS) oil production moved into deepwater. For example, in 1996 deepwater oil production in the Gulf of Mexico was just under 20% of the total oil produced in that region. In 2010, that deepwater percentage increased to 81% (Anderson et al. 2012). Meanwhile onshore, about 85% of oil that does spill from inland pipelines goes to containment areas around breakout tanks or to solid ground rather than surface waters. Also, spillage from coastal facilities often includes oil that spills into secondary containment. These containment systems provide essential lines of defense in preventing oil from spreading and reaching waterways and temporary containment of the spilled oil until a response can begin (Etkin 2009).

Gas and other hazardous substances may be released in a well blowout. A well blowout can take place when high pressure gas is encountered in the well and sufficient precautions, such as increasing the weight of the drilling mud, are not effective. The result is that gas or mud is suddenly and violently expelled from the well bore, followed by uncontrolled flow from the well. Blowout preventers, which immediately close off the open well to prevent or minimize any discharges, are required for all drilling and work-over rigs and are routinely inspected by AOGCC (AS 46.04.030). Blowout preventers greatly reduce the risk of a gas release. If a release occurs, however, the released gas will dissipate unless it is ignited by a spark. Ignition could result in a violent explosion.

Each well has a blowout prevention program developed before the well is drilled. Operators review bottom-hole pressure data from existing wells in the area and seismic data to learn what pressures might be expected in the well to be drilled. Engineers use this information to design a drilling mud program with sufficient hydrostatic head to overbalance the formation pressures from surface to the total depth of the well. They also design the casing strings to prevent various formation conditions from affecting well control performance.

2. Risk

Any time crude oil or petroleum products are handled there is a risk that a spill might occur. Oil spills associated with the exploration, development, production, storage and transportation of crude oil may occur from well blowouts or pipeline or tanker accidents. Petroleum activities may also generate chronic low volume spills involving fuels and other petroleum products associated with normal operation of drilling rigs, vessels and other facilities for gathering, processing, loading, and storing of crude oil. Spills may also be associated with the transportation of refined products to provide fuel for generators, marine vessels and other vehicles used in exploration and development activities.

Although there is a risk spills will result from exploration, production, storage, and transportation of oil and gas, these risks can be mitigated through prevention and response plans such as the Unified Plan and Subarea Contingency Plans (DEC 2001, 2009, 2010).

3. Prevention

Information gleaned from past spills has led to increased emphasis on prevention rather than response alone. Contingency planning, exercise and practice programs, improved safety standards, and other measures have helped reduce U.S. spillage (Etkin 2001).

For example, the Alaska Department of Environmental Conservation (DEC) and the U.S. Coast Guard are working on a multi-stage risk assessment of maritime transportation in the Bering Sea and Aleutian Archipelago. From this collaboration, came the Aleutian Islands Risk Assessment. It is a two phase approach that includes a Preliminary Risk Assessment (Phase A) followed by a Focused Risk Assessment (Phase B) (AIRA 2013). The Phase A Summary Report has been completed (AIRA 2011).

Risk Reduction Options (RRO) were analyzed and discussed in Phase A. Two key principles were applied to the RRO analysis: (1) prevention measures take priority over response measures, and (2) all measures should support the basis for the Advisory Panel’s recommendations. These recommendations were presented to the U.S. Coast Guard, State of Alaska, and local governments. Which measures will be adopted rests with these agencies (AIRA 2011).

4. Response

Response plans in relation to the sale area are included in the Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases (Unified Plan), the Aleutians Subarea Contingency Plan (AL SACP), and the Bristol Bay Subarea Contingency Plan (BB SACP) (DEC 2001, 2009, 2010).

A Unified Command structure of the Incident Command System (ICS) is the basis for government response and organization in the State of Alaska. The Unified Command brings together the Federal On-Scene Coordinator (FOSC), the State On-Scene Coordinator (SOSC), and the Responsible Party’s Incident Commander into one governing unit. If an immediate threat still exists to the health and safety of the local populace the Local On-Scene Coordinator (LOSC) will also be brought in (DEC 2001, 2009).

Response objectives include (DEC 2001, 2009, 2010):

- ensure safety of responders and the public;
- stop the source of the spill;
- deploy equipment to contain and recover the spilled product;
- protect sensitive areas (environmental, cultural, and human use);
- track the extent of the spill and identify impacted areas;
- cleanup contaminated areas and properly dispose of wastes;
- notify and update the public; and
- provide avenues for community involvement where appropriate.

Federal response action priorities/strategies general guidelines include (DEC 2001, 2009, 2010):

- safety of life;
- safety of vessel, facility and cargo;
- control sources of discharge;
- limit spread of pollution; and
- mitigate effects of pollution.

DEC, Division of Spill Prevention and Response is responsible for ensuring facilities prevent spills and take proper response actions when spills occur. One of their programs is the Prevention and Emergency Response Program (PERP). Its mission statement is as follows (DEC 2011):

> Protect public safety, public health and the environment by preventing and mitigating the effects of oil and hazardous substance releases and ensuring their cleanup through government planning and rapid response.

Because of statutory requirements, the State of Alaska implemented the following Response Objectives (DEC 2001, 2009, 2011):

- **safety**—ensure the safety of all persons involved in a response or exposed to the immediate effects of the incident;
- **public health**—ensure the protection of public health from the direct or indirect effects of contaminated drinking water, air or food;
- **environment**—ensure the protection of the environment, including natural and cultural resources, from the direct or indirect effects of contamination;
- **cleanup**—ensure adequate containment, control, cleanup and disposal by the responsible party, or take over the response when cleanup is judged inadequate;\
- **restoration**—ensure the assessment of damages from contamination and the restoration of property, natural resources and the environment; and
- **cost recovery**—ensure the recovery of costs and penalties for reimbursement to the Oil and Hazardous Substance Release Prevention and Response Fund for use in Future emergency response actions.

G. References

AIRA (Aleutian Islands Risk Assessment). 2011. Aleutian Islands Risk Assessment Project. Phase A Summary Report. http://www.aleutiansriskassessment.com/documents/110826AIRA_SummaryReportvFINALlr.pdf (Accessed February 15, 2013).

AIRA (Aleutian Islands Risk Assessment). 2013. Project Background. http://www.aleutiansriskassessment.com/background.htm (Accessed February 13, 2013).

Anderson, Cheryl McMahon, Melinda Mayes, and Robert LaBelle. 2012. Update of Occurrence Rates for Offshore Oil Spills. OCS report. BOEM 2012-069. BSEE 2012-069. http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Assessment/Oil_Spill_Modeling/AndersonMayesLabelle2012.pdf (Accessed February 15, 2013).

APSC (Alyeska Pipeline Service Company). 2011. Safety and Environment. Oil Spill Prevention, Response and Preparedness. http://www.alyeska-pipe.com/SafetyEnvironment/PreventionAndResponse (Accessed February 15, 2013).

Blodgett, R.B. and K.H. Clautice. 2005. Oil and gas seeps of the Puale Bay—Becharof Lake—Wide Bay region, northern Alaska Peninsula. Alaska Division of Geological and Geophysical Surveys. Preliminary Interpretive Report 2005-6, 13 p., 1 sheet. http://wwwdggs.dnr.state.ak.us/pubs/id/7189 (Accessed January 8, 2013).

Blodgett, R.B. and Bryan Sralla. 2008, A major unconformity between Permian and Triassic strata at Cape Kekurnoi, Alaska Peninsula; Old and new observationson stratigraphy and hydrocarbon potential, *in* Haeussler, P.J., and Galloway, J.P., eds. Studies by the U.S. Geological Survey in Alaska. 2006: U.S. Geological Survey Professional Paper 1739-E, 13 p. http://pubs.usgs.gov/pp/pp1739/e/ (Accessed January 18, 2013).

Bolger, G.W., and R.R. Reifenstuhl. 2008. Mercury injection capillary pressure and reservoir seal capacity of 26 outcrop samples, Miocene to Triassic age. in Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p.69-78. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

C-Core. 2008. Design Options for Offshore Pipelines in the US Beaufort and Chukchi Seas. US Department of the Interior, Minerals Management Service. Report R-07-078-519v2.0. http://www.bsee.gov/uploadedFiles/BSEE/Research_and_Training/Technology_Assessment_and_Research/tarprojects/500-599/577AA.pdf (Accessed February 13, 2013).

DEC (Alaska Department of Environmental Conservation). 2001. Spill Prevention and Response. Bristol Bay Subarea Contingency Plan for Oil and Hazardous Substance Discharge/Releases. A Subarea Plan of the Unified Plan for the State of Alaska. http://www.dec.alaska.gov/spar/perp/plans/scp_bb.htm (Accessed February 12, 2013).

DEC (Alaska Department of Environmental Conservation). 2009. Spill Prevention and Response. Aleutians Subarea Contingency Plan for Oil and Gas Hazardous Substance Discharge/Releases. A Subarea Plan of the Unified Plan for the State of Alaska. http://www.dec.alaska.gov/spar/perp/plans/scp_al.htm (Accessed February 12, 2013).

DEC (Alaska Department of Environmental Conservation). 2010. Spill Prevention and Response. Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases (Unified Plan). Change 3 (January 2010). http://www.dec.alaska.gov/spar/perp/plans/uc.htm (Accessed February 14, 2013).

DEC (Alaska Department of Environmental Conservation). 2011. Overview of the Prevention and Emergency Response Program. http://dec.alaska.gov/spar/perp/docs/perp.pdf (Accessed February 20, 2013).

Decker, P. 2006. A Brief Overview of Alaska Petroleum Systems. Alaska Division of Geological and Geophysical Surveys. 2006. A Brief Overview of Alaska Petroleum Systems. Division of Geological and Geophysical Surveys. Alaska GeoSurvey News. Vol. 9. No. 2. December 2006. 8p. http://www.dggs.alaska.gov/webpubs/dggs/nl/text/nl2006_002.PDF (Accessed October 10, 2012).

Decker, P.L. 2008. Mesozoic and Cenozoic source rock-characteristics, Puale Bay outcrops and North Aleutian Shelf COST #1 Well. in Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p. 11-33. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Decker, P.L., E.S. Finzel, K.D. Ridgway, R.R. Reifenstuhl, and R.B. Blodgett. 2005. Preliminary summary of the 2005 field season; Port Moller, Herendeen Bay, and Dillingham areas, Bristol Bay Basin. Alaska Peninsula: Alaska Division of Geological & Geophysical Surveys. Preliminary Interpretive Report 2005-7. 55 p. 2 sheets. http://www.dggs.alaska.gov/pubs/id/7190 (Accessed October 11, 2012).

Decker, P.L., R.R. Reifenstuhl, R.J. Gillis, and A. Loveland. 2008a. Revised geologic map and structural model of the Staniukovich Peninsula—Herendeen Bay area. in Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p. 161 to 176. 2 folded sheets in envelope. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Decker, P.L., R.R. Reifenstuhl, and R.J. Gillis. 2008b. Structural linkage of major tectonic elements in the Ugashik-Becharof Lakes region, northeastern Alaska Peninsula. in Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p.85 to 103. 1 folded sheet in envelope. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Detterman, R.L., M.E. Yount, and J.E. Case. 1981, Megafossil sample locality map, checklists, and stratigraphic sections of the Chignik and Sutwik Island quadrangles, Alaska: U.S. Geological Survey Miscellaneous field Studies Map MF-1053-N, 2 plates, scale 1:250,000. http://www.dggs.dnr.state.ak.us/pubs/id/12990 (Accessed October 12, 2012).

Detterman, R.L., J.E. Case, J.W. Miller, F.H. Wilson, and M.E. Yount 1996. Stratigraphic framework of the Alaska Peninsula: U.S. Geological Survey Bulletin 1969-A. 74 p. http://www.dggs.alaska.gov/webpubs/usgs/b/text/b1969a.PDF (Accessed October 11, 2012).

DOT&PF (Department of Transportation and Public Facilities). 2004. Southwest Alaska Transportation Plan. Revised edition, September 2004. http://www.dowlhkm.com/projects/SWAKTP/new_website/docs/swatp%202004.pdf(Accessed January 27, 2014).

DOT&PF (Department of Transportation and Public Facilities). 2011. Southwest Alaska Transportation Plan Update. Public Involvement Plan, Phase 1. August, 2011. http://www.dowlhkm.com/projects/SWAKTP/new_website/docs/swak%20pip.pdf (Accessed January 27, 2014).

DOT&PF (Department of Transportation and Public Facilities). 2014. Welcome to Alaska DOT&PF. http://www.dot.state.ak.us/ (Accessed January 28, 2014.

Dow, W.G. 1983, Geochemical analysis of North Aleutian Shelf Cost No. 1 well, Alaska: U.S. Minerals Management Service public well files – Robertson Research Report No. 823/135.

Dutrow, B.L. 1982. Petrologic description of Amoco Cathedral River No. 1 Sands: Consultant's report available to public as Alaska Geologic Materials Center (AGMC) Report No. 37, State of Alaska Geologic Materials Center, P.O. Box 772805, 18205 Fish Hatchery Road, Eagle River, AK. 99577-2805, 18 p http://www.dggs.alaska.gov/webpubs/dggs/gmc/text/gmc037.PDF. (Accessed February 20, 2013).

EPA (Environmental Protection Agency). 2011. Outdoor air-Industry, business, and home: Oil and natural gas production-Additional information. What are oil and natural gas production facilities. http://www.epa.gov/oaqps001/community/details/oil-gas_addl_info.html (Accessed February 11, 2013).

Etkin, D. S. 2001. Analysis of Oil Spill Trends in the United States and Worldwide. 2001 International Oil Spill Conference. http://www.environmental-research.com/publications/pdf/spill_statistics/paper4.pdf (Accessed February 14, 2013).

Etkin, D. S. 2009. Analysis of U.S. Oil Spillage. API Publication 356, Washington, D.C. http://www.api.org/environment-health-and-safety/clean-water/oil-spill-prevention-and-response/~/media/93371edfb94c4b4d9c6bbc766f0c4a40.ashx (Accessed February 14, 2013).

Finzel, E.S., R.R. Reifenstuhl, P.L. Decker, and K.D. Ridgway. 2005. Sedimentology, stratigraphy, and hydrocarbon reservoir-source rock potential, using surface and subsurface data, of Tertiary and Mesozoic strata, Bristol Bay Basin and Alaska Peninsula.. Alaska Division of Geological & Geophysical Surveys. Preliminary Interpretive Report 2005-4, 67 p.

http://www.dggs.alaska.gov/webpubs/dggs/pir/text/pir2005_004.PDF (Accessed October 10, 2012).

Furchtgott-Roth, Diana. 2013. Pipelines are safest for transportation of oil and gas. Manhattan Institute for Policy Research. Issue brief. No. 23 June 2013. http://www.manhattan-institute.org/html/ib_23.htm (Accessed January 27, 2014).

Galloway, W.E., 1974, Deposition and diagenetic alteration of sandstone in northeast Pacifi c arc-related basins; Implications for graywacke diagenesis: Geological Society of America Bulletin, v. 85, no. 3, p. 379–390. http://gsabulletin.gsapubs.org/content/85/3/379.abstract (Accessed October 26, 2012).

Hanson, B.M., 1957, Middle Permian limestone on Pacific side of Alaska Peninsula: American Association of Petroleum Geologists Bulletin, v. 41, no. 10, p. 2,376–2,378. http://aapgbull.geoscienceworld.org/content/41/10.toc (Accessed October 26, 2012).

Helmold, K.P. and D.W. Brizzolara. 2005, Reservoir quality of Tertiary sandstones from Bristol Bay basin, Alaska Peninsula: preliminary report: Alaska Division of Oil and Gas internal report; http://dog.dnr.alaska.gov/Publications/Documents/AlaskaPeninsula/Reservoir_Quality_Report.pdf (Accessed October 10, 2012).

Helmold, K.P., D.W. Brizzolara, and R.R. Reifenstuhl. 2008. Reservoir Quality of 84 Tertiary sandstones from three exploratory wells, Bristol Bay basin, Alaska Peninsula. in Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p.35-67. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Hite, D.M. 2004. Bristol Bay Native Corporation – Hydrocarbon Potential of Native Lands in the Bristol Bay Area, Southern Alaska. 80 p.

Institute for Energy Research (IER). 2013. Oil shipments by rail, truck, and barge up substantially. http://www.instituteforenergyresearch.org/2013/09/09/oil-shipments-by-rail-truck-and-barge-up-substantially/ (Accessed January 27, 2014).

ITOPF (International Tanker Owners Pollution Federation Limited). 2012. Oil Tanker Spill Statistics 2012. http://www.itopf.com/knowledge-resources/data-statistics/statistics/ (Accessed February 15, 2013).

Magoon, L.B., 1994, Tuxedni–Hemlock(!) petroleum system in Cook Inlet, Alaska, U.S.A., *in* Magoon, L.B., and Dow, W.G., eds., The petroleum system—from source to trap: American Association of Petroleum Geologists Memoir 60, p. 359–370.

Magoon, L.B., and D.E. Anders. 1992. Oil-to-source rock correlation using carbon–isotopic data and biological marker compounds, Cook Inlet–Alaska Peninsula, Alaska. in Moldowan, J.M., Albrecht, P., and Philip, R.P. eds. Biological Markers in Sediments and Petroleum: Prentice Hall, Englewood Cliffs, New Jersey. p. 241–274.Micropaleo Consultants. 2005. Northwestern Alaska Peninsula/Bristol Bay biostratigraphy study; North Aleutian Basin, Bering Sea, Alaska, 286 p., 22 plates. http://dog.dnr.alaska.gov/ResourceEvaluation/BiostratStudy.htm (Accessed January 9, 2013).

MOU (Memorandum of Understanding). 2003a. Memorandum of understanding between Alaska Deparment of Natural Resources and the Aleut Corporation to Hold concurrent oil and gas lease sales of state and TAC land in the Aleut regiona & to facilitate construction of a transportation infrastructure that will support these development projects. http://dog.dnr.alaska.gov/Publications/Documents/AlaskaPeninsula/MOU_ADNR_Aleut_Corporation.pdf (Accessed January 28, 2014).

New Developments in Upstream Oil and Gas Technologies: Hearing before the Committee on Energy and Natural Resources, United States Senate. 112th Cong. 2011. http://www.gpo.gov/fdsys/pkg/CHRG-112shrg67090/pdf/CHRG-112shrg67090.pdf (Accessed February 4, 2013).

Reifenstuhl, R.R. 2008. Introduction *in* Reifenstuhl, R.R. and Decker P.L. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p 1 to 10. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Reifenstuhl, R.R. and P.L. Decker. ed. 2008. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1, 221 p, 3 sheets. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Rigzone. 2013. Training. How it works. How does measurement-while-drilling (MWD) work? http://www.rigzone.com/training/insight.asp?insight_id=296&c_id=1 (Accessed February 11, 2013).

Schlumberger. 2013. Services and Products. Drilling services. Drilling applications. Extended-Reach Drilling (ERD). http://www.slb.com/services/drilling/specialty_drilling_applications/extended_reach_drilling.aspx (Accessed February 7, 2013).

Sherwood, K.W., J. Larson, C.D. Comer, J.D. Craig, and C. Reitmeier. 2006. North Aleutian basin OCS planning area assessment of undiscovered technically-recoverable oil and gas: U.S. Minerals Management Service Alaska OCS Region report, 138 p., 4 plates. http://www.boem.gov/uploadedFiles/BOEM/About_BOEM/BOEM_Regions/Alaska_Region/Resource_Evaluation/North-Aleutian-Basin-Assessment-Report.pdf (Accessed February 20, 2013).

Sneider, R.M., 1997, Petrophysical properties of seals, *in* Surdam, R.C., ed., Seals, traps and the petroleum system: Tulsa, OK, American Association of Petroleum Geologists Memoir 67, 317 p.

SPCO (State Pipeline Coordinator's Office). 2011. Personal communication from Louis Kozisek, Chief Engineer, SPCO to Mike Thompson, State Pipeline Coordinator, SPCO. Memo Re: Opinion on Aboveground vs. HDD Pipeline Crossing for the Nigliq Channel. April 12, 2011. http://dnr.alaska.gov/commis/pco/documents/louis_cd5_paper.pdf (Accessed February 13, 2013).

Turner, R.F., ed., 1988, Geological and operational summary, North Aleutian Shelf COST No. 1 well, Bering Sea, Alaska:U.S. Minerals Management Service, OCS Report MMS 88-0089, 256 p., 2 plates. http://www.boem.gov/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Resource_Evaluation/Geological_and_Geophysical_Data_Acquisition/MMS88_0089NAleutianShelf.pdf (Accessed October 11, 2012).

USFWS (U.S. Fish and Wildlife Service). 1985. Alaska Peninsula National Wildlife Refuge final comprehensive conservation plan, environmental impact statement and wilderness review. http://books.googleusercontent.com/mwg-internal/de5fs23hu73ds/progress?id=vEcTOMahL/ (Accessed January 28, 2014).

USFWS (U.S. Fish and Wildlife Service). 1988. Alaska Maritime National Wildlife Refuge. Comprehensive conservation plan. Environmental impact statement. Wilderness review. Volume I. http://books.googleusercontent.com/mwg-internal/de5fs23hu73ds/progress?id=rgNCymkOD4 (Accessed January 28, 2014).

USGS (United States Geological Survey). 1996, 1995 National Oil and Gas Assessment Conventional Plays within the Southern Alaska Province: U.S. Geological Survey Digital Data Series DDS-30, USGS Central Energy Team, Denver, Colorado. http://pubs.usgs.gov/dds/dds-030/ (Accessed October 11, 2012).

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* The Geology of North America. Vol. G-1. The Geology of Alaska. The Geological Society of America. P. 367 – 388. http://www.dggs.alaska.gov/webpubs/outside/text/dnag_complete.PDF (Accessed October 10, 2012).

Van Dyke, K. 1997. Fundamentals of petroleum, *fourth edition*. University of Texas, Petroleum Extension Service, Austin, TX.

Wang, J., 1987, Sedimentology of Norian (Late Triassic) cherts and carbonates from the Pennisular terrane: Puale Bay, Alaska Peninsula; Syracuse, N.Y., Syracuse University, M.S. thesis, 124 p.

Wang, J., C.R. Newton, and L. Dunne. 1988, Late Triassic transition from biogenic to arc sedimentation on the Peninsular terrane, Puale Bay, Alaska Peninsula: Geological Society of America Bulletin, v. 100, no. 9. p.1,466–1,478. http://gsabulletin.gsapubs.org/content/100/9/1466.abstract (Accessed October 25, 2012).

Whalen, M.T. and T.W. Beatty. 2008. Kamishak Formation, Paule Bay. in Reifenstuhl, R.R. and P.L. Decker. ed. Bristol Bay – Alaska Peninsula Region, Overview of 2004-2007 Geologic Research. Alaska Division of Geological and Geophysical Surveys Report of Investigation 2008-1. p.105 to 129. http://www.dggs.alaska.gov/webpubs/dggs/ri/text/ri2008_001.PDF (Accessed October 10, 2012).

Wilson, F.H., 1985, The Meshik Arc – an Eocene to earliest Miocene magmatic arc on the Alaska Peninsula. Alaska Division of Geological and Geophysical Surveys Professional Report 88. 14 p. http://www.dggs.alaska.gov/webpubs/dggs/pr/text/pr088.PDF (Accessed February 20, 2013).

Wilson, F.H., R.L. Detterman. and J.E. Case. 1985. The Alaska Peninsula terrane - A definition: U.S. Geological Survey Open-File Report 85-470, 20 p. http://www.dggs.alaska.gov/webpubs/usgs/of/text/of85-0450.PDF (Accessed October 11, 2012).

Wilson, F.H., R.L. Detterman, and G.D. DuBois. 1999. Digital Data for Geologic framework of the Alaska Peninsula, Southwest Alaska, and the Alaska Peninsula Terrane: U.S. Geological Survey Open File Report 99-317. 40 p. http://geopubs.wr.usgs.gov/open-file/of99-317/ (Accessed October 11, 2012).