North Aleutian Basin Planning Area (Alaska) – Province Summary

2006 Oil and Gas Assessment

Location

The North Aleutian Basin Outer Continental Shelf (OCS) Planning Area encompasses an area of 52,234 square miles and includes most of the southeastern part of the Bering Sea continental shelf (fig. 1). The North Aleutian basin proper is about 17,500 square miles in area and underlies the northern coastal plain of the Alaska Peninsula and the waters of Bristol Bay (fig. 2). North Aleutian basin is also referred to as the "Bristol Bay" basin. Water depths range from 15 to 700 feet and in the area of the most important prospects the water depths are approximately 300 feet.

Leasing and Exploration

The prospects in the central part of the North Aleutian basin have long been the focus of exploration interest in North Aleutian basin and several were leased for total high bids of $95.4 million (23 blocks) in OCS lease sale 92 in 1988 (fig. 2). All of the 1988 leases have been returned to the U.S. Government and are no longer active. In this assessment, as well as in past assessments, most of the hypothetical, undiscovered oil and gas resources of the North Aleutian Basin OCS Planning Area are associated with the prospects in the central part of the North Aleutian basin.

Onshore, nine exploration wells have tested fold and thrust-fault structures along the southern edge of the North Aleutian basin. Several offshore wells in the St. George basin tested age-equivalent strata to the west. The principal point of geological control for the Tertiary-age fill in the North Aleutian basin is the North Aleutian Shelf COST 1 well, drilled in 1983 by an industry consortium led by ARCO Exploration Company. None of these wells encountered any sizeable accumulations of oil or gas, although several wells detected oil and gas shows and two onshore wells tested minor gas pools at rates up to 90 thousands of cubic feet per day.

North Aleutian and Amak basins (located in fig. 3) are covered by gridded (1 to 5 mile spacing in prospective areas) two-dimensional seismic data mostly acquired in the period from 1975 to 1988 (Sherwood et al., 2006, fig. 3). Seismic data gathered to date within the North Aleutian Basin OCS Planning Area consists of 61,438 line miles of conventional, two-dimensional, common-depth-point (CDP) data and 3,234 line miles of shallow-penetrating, high-resolution (HRD) data. Airborne magnetic data in the area covers 9,596 line miles and airborne gravity data covers 6,400 line miles.

In October 1989, the North Aleutian Basin Planning Area was placed under a Congressional moratorium which banned U.S. Department of Interior expenditures in support of any petroleum leasing or development activities in North Aleutian Basin as well as the Atlantic, Pacific, and eastern Gulf of Mexico OCS Planning Areas. Bristol Bay is the center of a very important commercial salmon fishery. The North Aleutian moratorium reacted to widespread demands for fisheries protection in Bristol Bay by Native organizations, Native villages, local fishing interests, and the State of Alaska following the March 1989 *Exxon Valdez* grounding and oil spill in Prince William Sound, Alaska. This moratorium was extended by Congress several times during the 1990's. Offshore leases that had been issued in the 1988 OCS Sale 92 in the North Aleutian basin were returned to the Federal government in a 1995 buy-back agreement. On 12 June 1998, President William Clinton issued an Executive Order reinforcing the moratorium, as a *Presidential Withdrawal*, on North Aleutian Basin as well as the Atlantic, Pacific, and eastern Gulf of Mexico continental shelves until 30 June 2012. The *Presidential Withdrawal* for North Aleutian basin and other areas still stands but can be revoked by the President. In the FY-2004 Congressional bill appropriating the budget for the U.S. Department of Interior, the language forbidding funding of oil and gas activities (i.e., the "Congressional moratorium") in the North Aleutian Basin OCS Planning Area was dropped. The moratoria language in the bill was retained for the other moratoria areas listed above. This action effectively ended the Congressional moratorium on oil and gas activities in the North Aleutian Basin OCS Planning Area. In response to expressions of industry interest and support from local communities, the MMS has re-opened the possibility of future oil and gas lease sales in the North Aleutian basin. The MMS draft proposal for the 2007-2012 leasing program (MMS, 2006) initiates the environmental studies and public process that could lead to future lease sales. The draft plan as published proposes North Aleutian basin lease sales for years 2010 and 2012, contingent upon a lengthy public review, public support, favorable resolution of environmental issues, and cancellation of the standing *Presidential Withdrawal*.

On 26 October 2005, the State of Alaska received 37 bids on 37 tracts in the Port Moller area (fig. 2). High bids totaled $1.27 million and all bids were submitted by either Shell Offshore Inc. (33 tracts, $0.95 million) or Hewitt Mineral Corp. (4 tracts, $0.31 million). The tracts cover areas where thrust faulted and folded Mesozoic and Cenozoic rocks are exposed at the surface (Wilson et al., 1995).

Geologic Setting of North Aleutian Basin

The North Aleutian basin is one of several basins of primarily Tertiary age that dot the Bering Sea shelf. The basin is roughly 100 miles wide and 400 miles in length and reaches depths of 20,000 feet in its deepest parts. The North Aleutian basin extends onshore beneath the lowlands along the north shore of the Alaska Peninsula, where it has been penetrated by several wells. At its west end, a series of arches isolate the basin from the similar St. George and Amak basins (fig. 3), where Tertiary sediment thicknesses reach 40,000 feet and 12,500 feet, respectively (Comer et al., 1987). Along the southern margin of the North Aleutian basin, the Tertiary basin fill is deformed in fold and thrust-fault structures like those widely exposed on the Alaska Peninsula. The interior of the North Aleutian basin is dominated by uplifted fault blocks that have domed the overlying strata.

Nature of Basement Beneath North Aleutian Basin

In the western Alaska Range (northwest of the study area), the Bruin Bay fault (fig. 3) forms a regional contact between Mesozoic "granitic" volcano-plutonic rocks on the north and Mesozoic sedimentary rocks on the south (Magoon et al., 1976). The volcano-plutonic rocks on the north are the roots of a Mesozoic magmatic arc and range in K-Ar ages from 179 to 107 Ma (Magoon et al., 1976, sh. 3), or Middle Jurassic to mid-Cretaceous, respectively, in equivalent stratigraphic ages. The Mesozoic sedimentary rocks south of the Bruin Bay fault represent a Mesozoic basin that flanked the contemporary volcanic arc to the north (Bally and Snelson, 1980).

Southwest of Becharof Lake the Bruin

Bay fault passes beneath volcanic rocks and glacial sediments of Quaternary age of the Bristol Bay lowlands. Farther southwest, the location of any extension of the Bruin Bay fault is unknown and a matter for speculation.

A regional magnetic intensity map for the southern Bering Sea shelf west of 162° W.L. published by Childs et al. (1981) shows two principal magnetic domains with very different field characters. In the north, the map shows high-frequency, high-intensity magnetic anomalies. In the south, the map shows low-frequency, low-intensity magnetic anomalies. The two magnetic domains are clearly separated by a sharp, west-trending line that may represent the extension of the Bruin Bay fault into the southern Bering Sea.

Sherwood et al. (2006, p. 13-15) argue that the northern magnetic domain in the mapping by Childs et al. is the southwestward, offshore extension of the Mesozoic magmatic arc terrane exposed north of the Bruin Bay fault in the western Alaska Range. Similarly, the southern magnetic domain is regarded as the southwestward offshore extension of the folded Mesozoic sedimentary terrane exposed south of the Bruin bay fault. A hypothetical trace of the Bruin Bay fault is located as a dashed line in figure 3.

The most important gas and oil prospects in the North Aleutian basin (partly located by Sale 92 leases) occupy the part of the basin that overlies the Mesozoic magmatic terrane north of the Bruin Bay fault (fig. 3). It is very unlikely that hydrocarbons in any quantity can be sourced out of the Mesozoic magmatic arc terrane beneath the part of the North Aleutian basin north of the Bruin Bay fault Any analogy to the petroleum system of northern Cook Inlet, where oil generated in an underlying Mesozoic basin has charged shallower traps in Cenozoic rocks, probably cannot be extended to this part of the North Aleutian basin.

Potential Traps

Most mapped prospects in the North Aleutian basin proper are simple domes draped over the crests of fault-bounded basement uplifts. These domes range up to 93,000 acres in closure area. In the central part of the North Aleutian basin 65 miles northwest of Port Moller, these domes are surrounded by deep parts of the basin where the lowermost strata have been heated to temperatures sufficient for conversion of organic matter to oil and gas. Oil and gas generated in these basin deeps should have migrated upward into the domes over the basement uplifts.

The dominant geological feature of the southwest part of the North Aleutian Basin OCS Planning Area is the Black Hills uplift. Over the Black Hills uplift, the Tertiary sequence is thin (2,000 to 5,000 ft) and thermally immature. However, the area is underlain by Mesozoic rocks that might form a source for oil. On the Black Hills uplift, broad domes in Tertiary strata range up to 133,000 acres in area.

Mesozoic Stratigraphy and Reservoir Formations

A stratigraphic chart for the Mesozoic rocks of the Alaska Peninsula is presented in figure 4. Sandstones and conglomerates that might form reservoirs for petroleum include the Talkeetna, Naknek, Staniukovich, Herendeen, and Hoodoo (or equivalent Chignik) Formations. Because the Mesozoic basin in which these strata were deposited flanked a volcanic arc, most clastic sediments are rich in volcanic and plutonic rock fragments. Upon burial, the volcanic material readily degraded into laumontite and other zeolite-group minerals that fully occluded intergranular porosity. Generally, younger sandstone formations contain less volcanic debris because of recycling of older clastic formations and winnowing of volcanic particles made susceptible to disintegration by chemical and physical weathering (Burk, 1965, fig. 10). Younger formations have also been less deeply buried because of their position at the top of the sedimentary stack and have presumably suffered less from compaction and thermally-driven pore-filling diagenesis.

Cenozoic Stratigraphy, Reservoir Formations, and Play Sequences

The most complete point of stratigraphic control for the Tertiary-aged North Aleutian basin fill is the North Aleutian Shelf COST 1 stratigraphic test well. The stratigraphy of the COST well is presented in figure 5.

Three play sequences based on COST well stratigraphy are defined for purposes of this assessment. Each play sequence embraces groups of rocks that share some commonality in reservoir formation characteristics and relationships to prominent unconformities and seismic markers.

The Milky River Biogenic Gas (play 4) play sequence ranges in age from Early Pliocene to Holocene and includes the upper part of the Milky River Formation and overlying unnamed Quaternary-age rocks. The play sequence at the COST well consists of middle to outer neritic unconsolidated lithic pebbly sands, mud, ooze, and clay (Turner et al., 1988, p. 14).

The Bear Lake-Stepovak (plays 1, 3) play sequence ranges in age from Late Oligocene to Early Pliocene in the North Aleutian Shelf COST 1 well and includes the upper part of the Stepovak Formation, the entire Bear Lake Formation, and the lower part of the Milky River Formation. The Bear Lake-Stepovak play sequence at the North Aleutian Shelf COST 1 well is rich (61% of play sequence) in thick (up to 277 feet), porous (up to 40+% porosity), and permeable (up to 7,722 md) sandstones (Sherwood et al., 2006, figs. 11-16). The play sequence contains a total of 3,120 net feet of sandstones in beds greater than 10 feet thick (an assumed practical minimum thickness for productive reservoir) and 1,443 net feet in beds over 100 feet thick. Because of the ample, thick sandstones and the excellent preservation of porosity and permeability, the Bear Lake-Stepovak play sequence is the most attractive reservoir target in the North Aleutian basin.

The Tolstoi (play 2) play sequence ranges in age from Early Eocene to Early Oligocene in the North Aleutian Shelf COST 1 well and includes the Tolstoi Formation and the lower, shaly part of the Stepovak Formation (9,555-10,380 ft bkb). The Tolstoi play sequence is characterized by sparse (10% to 30% of interval), thin (maximum = 57 ft) sandstones. Below 10,380 feet, the sandstones are largely impermeable because diagenesis (to clay and zeolites) has softened volcanic clasts and the sandstone grain framework has collapsed, as described in petrographic studies by AGAT (1983, p. 2) and Turner et al. (1988, p. 23-24).

Thermal Maturity of North Aleutian Basin Fill

Sherwood et al. (2006, figs. 17-19) summarize vitrinite reflectance data for the North Aleutian Shelf COST 1 well and illustrate areas where the North Aleutian basin fill achieves sufficient thermal maturity to generate petroleum. Figure 6 maps the thicknesses of Tertiary-age strata that lie within the oil generation zone of thermal maturity. Areas highlighted in gray in figure 6 are potential generation “kitchens” for gas, condensate, and (possibly) oil. The North Aleutian basin generation “kitchen” is segmented by the presence of a massive 33-39 Ma volcanic center penetrated at the Port Heiden 1 and Ugashik 1 wells.

Source Rock Potential

We recognize two potential sources of thermogenic petroleum in North Aleutian basin: 1) Mesozoic sedimentary rocks that underlie the southwest part of North Aleutian basin and the Black Hills uplift; and 2) Cenozoic rocks that comprise the North Aleutian basin fill.

Mesozoic Source Rocks

The principal point of control for the source rock potential of Mesozoic rocks in the North Aleutian Basin OCS Planning Area is the Cathedral River 1 well. Some indicators for source rock potential of the Mesozoic rocks in this well are illustrated by Sherwood et al., (2006, fig. 20).

For most of the Mesozoic sequence penetrated by the Cathedral River 1 well, the rocks are rated as poor to fair sources for gas. However, shales and tuffaceous limestones in the interval from 8,700 to 9,300 feet in the Kialagvik Formation appear to rate as "good" potential sources for oil and wet gas. In addition, cherty shales and marlstones in the interval from 12,000 to 12,700 feet in the Talkeetna Formation also appear to form "good" sources for oil and wet gas. Unfortunately, the pyrolysis data are inconclusive because the well samples may have been contaminated by drilling mud additives (Peters, 1986, fig. 12; Sherwood et al., 2006, p. 21-22).

Thermal maturity data indicate that the rocks in the Cathedral River 1 well were previously much more deeply buried (Sherwood et al., 2006, p. 22, fig. 20). Because the well is located on the Black Hills uplift where Mesozoic strata are unconformably overlain by Eocene-age rocks (north flank), it appears that the thermal maturation occurred during a Mesozoic cycle of deep burial. The Mesozoic oil sources in this area may have generated and expelled their oil long before the deposition of Tertiary-age reservoir sandstones or the formation of drape anticlines in Oligocene-Miocene strata atop the Black Hills uplift.

Tertiary Source Rocks

The principal point of control for the source rock potential of the Tertiary-age fill for North Aleutian basin is the North Aleutian Shelf COST 1 well. A graphical summary of source rock geochemical information is presented by Sherwood et al. (2006, plate 4), but some indicators for source potential (TOC) and hydrocarbon type (hydrogen index or "HI") in the COST well are shown in figure 7. Total organic carbon (TOC) data suggest that source potential ranges from "poor" to "very good." Hydrogen index (HI) values suggest mostly gas sources with some intervals where HI>300 that might be capable of generating oil. Sample descriptions reveal that most samples with TOC values exceeding 1.0% include coal, as either discrete fragments in cuttings or coaly laminations in core samples. In the several depth intervals below 8,000 feet in figure 7 where HI>300, we note that nearly all of the elevated HI values are associated with well samples described as containing coal. The key question then is whether or not these high-HI coals, or possibly non-coal lithologies mixed with coal material in samples, are legitimately capable of generating oil. Sherwood et al. (2006, fig. 22) summarize elemental data for coal-bearing (sidewall and conventional core) samples and conclude that the coals are hydrogen-poor and offer little potential for generation of liquid hydrocarbons.

Sherwood et al. (2006, p. 21-26), Robertson Research (1983, p. 1-9) and Turner et al. (1988, p. 190-191) unanimously conclude that the Tertiary sequence penetrated by the North Aleutian

Shelf COST 1 well contains primarily Type III organic matter. This gas-prone organic matter occurs in coal beds or is dispersed as finely divided material in clastic rocks and forms poor to very good sources for gas, with minor potential for condensates and light oil.

Oil and Gas Occurrences and Biomarker Correlations

Gas was recovered by three flow tests at rates summing to 90 Mcfg/d from 3 zones in the Tolstoi Formation in the Becharof Lake 1 well. Gas was also recovered in flow tests from two intervals in the Tolstoi Formation at rates of 5 to10 Mcfg/d (with 300-400 barrels of water per day) in the David River 1/1A well. Oil and gas shows were noted elsewhere in wells offshore and in wells on the Alaska Peninsula (annotated in fig. 2).

Gas seeps are observed as gas "chimneys" in some proprietary seismic profiles on the Black Hills uplift. Onshore, oil and gas seeps are known primarily from the area near the east end of Becharof Lake, where they are observed along the axes of exposed anticlines in Mesozoic rocks or along important faults. Gas seep samples are composed mostly of carbon dioxide and are probably the result of magmatic intrusions that are decarbonating limestones in the subsurface. Reifenstuhl (2005) however reports a gas seep from that consists of 91% methane, 7% nitrogen, and 2% carbon dioxide. Natural gas recovered from the Becharof Lake 1 well consists of 87.5% methane, 4.7% ethane, 2.3% propane, 0.8% butane, 1.0% hydrogen, and 3.7% "other" gases (AOGCC, 1985, DST data). This gas is very different from most of the nearby seeps which are mostly carbon dioxide (Sherwood et al., 2006, fig. 23).

Oil seeps emanating from Jurassic rocks along the axes of exposed anticlines attracted the earliest exploration drilling to the Alaska Peninsula in the early 1900's. Geochemical studies of these seep oils suggest that they were sourced from Upper Triassic rocks (unnamed) like those exposed at Puale Bay (locale posted in fig. 2), with possible contribution from Middle Jurassic rocks (Kialagvik Fm.) like those exposed in the same area (Magoon and Anders, 1992).

Modest oil and gas shows and gas "wetness" values of 30% to 95% were noted below 15,450 feet bkb in the North Aleutian Shelf COST 1 well. These shows and the high gas wetness values may signal the presence of migrated liquid petroleum. It is therefore important to determine the source of these liquid hydrocarbons. Were they generated by Type III organic matter like that dominating the Tertiary rocks penetrated by the COST well? Or, did these liquid hydrocarbons originate from unseen oil sources within Mesozoic rocks beneath the COST well?

To try to identify the source of the liquid hydrocarbons below 15,450 ft in the COST well, we conducted extraction and biomarker studies on the show interval. The two extractions obtained in this study supplement data previously obtained by Robertson Research (1983). The extract data are discussed by Sherwood et al., (2006, p. 28-30), who conclude that the oil shows in the interval from 15,450 to 16,800 feet bkb in the North Aleutian Shelf COST 1 well originated from nonmarine Tertiary rocks rather than marine Mesozoic rocks. This interpretation extends from the following observations:

1. Low Sulfur Content Suggests Tertiary Sources.
2. Isoprenoid Ratios Are Terrestrial.
3. Pristane/Phytane Ratios are Terrestrial
4. Carbon Isotopes Correlate to Nonmarine Tertiary, as shown in figure 8.
5. Deficit of Saturates Correlates to

Tertiary Extracts

6. C30 steranes are absent, indicating a terrestrial source.
7. Oleanane is present, suggesting a Late Cretaceous or younger source.

Petroleum System—Critical Events

A "Lopatin"-style (Lopatin, 1971) burial history model for the North Aleutian Shelf COST 1 well is shown in figure 9 along with some timelines for critical events in the hypothetical petroleum system for the offshore part of the North Aleutian basin. All of the strata beneath 10,372 ft bkb in the COST well (total thickness of thermally mature rocks at COST well site estimated at 10,430 ft) have achieved thermal exposures sufficient for generation of gas and oil.

The rocks at the bottom of the North Aleutian Shelf COST 1 well are shown to enter the early oil generation zone (TTI>3) at about 31.7 Ma. The base of the well entered the peak oil generation zone (TTI>10) at 27.0 Ma and hydrocarbon generation presumably continues at present.

The thermal maturation of the un-penetrated strata projected to lie beneath the bottom of the COST well represents the earliest opportunity for generation of petroleum. This deeper package of strata entered the early oil generation window (TTI>3) as early as 38.5 Ma and the peak oil generation zone (TTI>10) at 34.4 Ma.

Deposition of the principal reservoir—the Bear Lake-Stepovak play sequence—began about 28.5 Ma and continued up to about 4.5 Ma. Sometime between 34.4 and 27.0 Ma, the lowermost 3,000 ft of basin fill reached peak oil generation. At this time, the lower part of the Bear Lake-Stepovak sequence and associated traps were certainly in place to capture migrating petroleum. As the Bear Lake-Stepovak sequence accumulated over time and the drape folds over basement uplifts grew, they presumably continued to receive thermogenic gas and oil generated and expelled out of the flanking areas of deepening burial.

Petroleum Systems and Charging of Plays

The major elements of the petroleum systems hypothesized for the North Aleutian Basin OCS Planning Area are illustrated in a schematic cross section in figure 10A. For the main part of the North Aleutian basin, traps are hypothesized to be charged by gas, condensate, and oil originating from deeply buried, gas-prone source rocks of Tertiary age. Biogenic gas sourced from bacterial action in coals may be an important additional source for gas in the drape folds over basement uplifts. For the southwest part of the planning area, traps in Mesozoic sandstones are hypothesized to be charged by original oil migration from Mesozoic oil source rocks. Traps in Tertiary sandstones overlying the oil-prone Mesozoic rocks are hypothesized to be charged by re-migration of oil out of disrupted Mesozoic reservoirs.

Play Definition

Plays were defined first on the basis of reservoir characteristics, for which the stratigraphic sequence serves as proxy. Further separations were made on the basis of structural setting and hydrocarbon charge models (source type [oil vs. gas] and access [length and integrity of migration path]). The relative dispositions of plays are shown in figure 10B.

The Bear Lake-Stepovak sequence was defined so as to capture the main reservoir package between seismic horizons "A" and "C" (fig. 5), which is characterized by abundant, thick, porous, and permeable sandstones. The Bear Lake-Stepovak sequence is draped over basement uplifts in the southwest part of the North Aleutian basin and forms the key exploration play in the basin. The Bear Lake-Stepovak play sequence can be traced to the Black Hills uplift, where it is also draped over basement uplifts. But the Black Hills uplift is treated as a separate play because it has access to hypothetical oil-prone sources in the underlying Mesozoic assemblage. The Black Hills uplift has limited access (large distances across highly faulted areas) to the deeply buried gas-prone Tertiary age sources that are hypothesized to charge the main Bear Lake-Stepovak play. The Tolstoi play sequence hosts poor-quality reservoir sandstones (thin and impermeable) and is involved in flank traps against basement uplifts. The Tolstoi sequence is thus set apart into a third play.

A fourth play identifies low-pressure biogenic gas resources in shallow Plio-Pleistocene strata of glacial and marine origins.

The substrate of Mesozoic rocks beneath the North Aleutian basin in divided into a southern province of deformed sedimentary rocks (play 5) and a northern province of "granitic" volcano-plutonic rocks (play 6). The Mesozoic deformed sedimentary rocks on the south include rocks correlative to regional oil sources and form an oil play. The granitic Mesozoic province on the north forms the cores of basement uplifts and if properly fractured, might form a reservoir for hydrocarbons.

Oil and Gas Resources of North Aleutian Basin

The 2006 assessment of the North Aleutian Basin OCS Planning Area identified six exploration plays. Most (61%) of the hypothetical, undiscovered oil and gas resources are associated with play 1—the Bear Lake-Stepovak play. The risked, technically-recoverable, undiscovered hydrocarbon energy endowment of the North Aleutian Basin OCS Planning Area ranges up to 6,647 Mmboe (F05), with a mean value or expectation of 2,287 Mmboe, as shown in tables 1, 3, and 4 and figure 11. The planning area is gas-prone, with sixty-seven percent of the undiscovered hydrocarbon energy endowment consisting of natural gas. Mean risked, undiscovered total gas (sum of free gas and solution gas in oil) resources total 8.622 Tcf but could range up to a maximum (F05) potential of 23.278 Tcf. Mean risked, undiscovered liquid petroleum (sum of free oil and condensate from gas) resources are estimated at 753 Mmb but could range up to a maximum (F05) potential of 2,505 Mmb.

North Aleutian Basin OCS Planning Area, Undiscovered Technically-Recoverable Oil & Gas

Assessment Results as of November 2005

Resource Commodity (Units)	Resources *		
	F95	Mean	F05
BOE (Mmboe)	91	2,287	6,647
Total Gas (Tcfg)	0.404	8.622	23.278
Total Liquids (Mmbo)	19	753	2,505
Free Gas (Tcfg)	0.401	8.393	22.487
Solution Gas (Tcfg)	0.003	0.229	0.791
Oil (Mmbo)	9	545	1,948
Condensate (Mmbc)	10	208	556

** Risked, Technically-Recoverable*

F95 = 95% chance that resources will equal or exceed the given quantity

F05 = 5% chance that resources will equal or exceed the given quantity

BOE = total hydrocarbon energy, expressed in barrels-of-oil-equivalent, where 1 barrel of oil = 5,620 cubic feet of natural gas

Mmb = millions of barrels

Tcf = trillions of cubic feet

Table 1

The 5 quantified plays in the North Aleutian Planning Area are estimated to contain a maximum of 119 pools. The mean conditional (un-risked) size of the largest pool in the North Aleutian basin is 827 Mmboe. In an all-gas case, this is equivalent to 4.65 Tcfge and is nearly twice the size of the largest gas field in Cook Inlet (Kenai gas field, 2.427 Tcfg EUR). At maximum (F05) size, the largest pool in the North Aleutian basin could contain 14.02 trillions of cubic feet of natural gas (or 2,495 Mmboe). Table 2 shows the conditional sizes of the 10 largest undiscovered pools in the North Aleutian Basin Planning Area.

North Aleutian Basin OCS Planning Area, Alaska, 2006 Assessment, Conditional BOE Sizes of Ten Largest Pools				
Assessment Results as of November 2005				
Pool Rank	**Play Number**	**BOE Resources * (Mmboe)**		
		F95	**Mean**	**F05**
1	1	187	827	2495
2	3	20	378	1302
3	1	106	378	816
4	1	65	245	542
5	2	61	208	467
6	1	41	174	382
7	6	9	148	469
8	1	26	130	290
9	2	34	124	248
10	3	6	110	365

** Conditional, Technically-Recoverable, Millions of Barrels Energy-Equivalent (Mmboe), from "PSRK.out" file*

F95 = 95% chance that resources will equal or exceed the given quantity

F05 = 5% chance that resources will equal or exceed the given quantity

BOE = total hydrocarbon energy, expressed in barrels-of-oil-equivalent, where 1 barrel of oil = 5,620 cubic feet of natural gas

Table 2

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Links to Summaries for Individual Plays and Appended Items

Play 1 (Bear lake-Stepovak), North Aleutian Basin, Assessment Summary

Play 2 (Tolstoi), North Aleutian Basin, Assessment Summary

Play 3 (Black Hills Uplift-Amak Basin), North Aleutian Basin, Assessment Summary

Play 4 (Milky River Biogenic Gas), North Aleutian Basin, Assessment Summary

Play 5 (Mesozoic Deformed Sedimentary Rocks), North Aleutian Basin, Assessment Summary

Play 6 (Mesozoic Buried Granitic Hills), North Aleutian Basin, Assessment Summary

North Aleutian Basin Plays-Assessment Results by Commodity (Excel Format)

North Aleutian Basin Plays-Input Data Tables (Excel Format)

North Aleutian Basin Plays-Pool Size Models (Txt Format)

North Aleutian Basin Plays-Simulation Pools-Statistics (Excel Format)

North Aleutian Basin Province-Assessment Results (Excel Format)

2006 Assessment Results for North Aleutian Basin OCS Planning Area
Risked, Undiscovered, Technically Recoverable Oil and Gas Resources, as of November 2005

		BOE Resources (Mmboe)			Oil Resources (Mmbo)			Gas-Condensate Liquid Resources (Mmbo)			Free* Gas Resources (Tcfg)			Solution Gas Resources (Tcfg)			Total Liquid Resources (Mmbo)			Total Gas Resources (Tcfg)		
Play Number	**Play Name**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**	**F95**	**Mean**	**F05**
1	**Bear Lake-Stepovak** (Oligocene-Miocene)	0	1,400	3,749	0	271	828	0	136	349	0.000	5.473	14.131	0.000	0.113	0.330	0	406	1,176	0.000	5.586	14.461
2	**Tolstoi** (Eocene-Oligocene)	91	568	1,293	9	62	139	10	61	141	0.401	2.476	5.640	0.003	0.025	0.053	19	123	280	0.404	2.501	5.693
3	**Black Hills Uplift-Amak Basin** (Eocene-Miocene)	0	210	1,077	0	149	706	0	6	38	0.000	0.249	1.588	0.000	0.063	0.289	0	155	743	0.000	0.312	1.877
4	**Milky River Biogenic Gas** (Plio-Pleistocene)	Play 4 Assessed with Negligible Resources																				
5	**Mesozoic Deformed Sedimentary Rocks** (Triassic-Cretaceous)	0	41	197	0	38	183	0	0	0	0.000	0.000	0.000	0.000	0.017	0.079	0	38	183	0.000	0.017	0.079
6	**Mesozoic Buried Granitic Hills** (Jurassic-Cretaceous Magmatic Rocks)	0	67	330	0	26	93	0	5	29	0.000	0.195	1.128	0.000	0.010	0.041	0	30	122	0.000	0.206	1.169
Sum of All Plays**		**91**	**2,287**	**6,647**	**9**	**545**	**1,948**	**10**	**208**	**556**	**0.401**	**8.393**	**22.487**	**0.003**	**0.229**	**0.791**	**19**	**753**	**2,505**	**0.404**	**8.622**	**23.278**

* Free gas, occurring as gas caps associated with oil and as oil-free gas pools (non-associated gas).

** Values as reported out of *Basin Level Analysis-Geologic Scenario* aggregation module in *GRASP*, *"Volume Ordered"* aggregation option. Total liquids and total gas values were obtained by summing resource values for means and fractiles of component commodities. Play resource values are rounded and may not sum to totals reported from basin aggregation.

*** Calculated as the ratio of total gas to total liquids at mean values (1 barrel of liquids = 5,620 cubic feet of gas at standard conditions). Given as ratio between fractions summing to 100.

BOE, total energy, in millions of barrels (5,620 cubic feet of gas per barrel of oil, energy-equivalent); Mmbo, millions of barrels of oil or liquids; Tcfg, trillions of cubic feet of natural gas

Table 3. Summary of North Aleutian Basin Planning Area assessment results for ultimate technically recoverable resources (UTRR) by play.

Province Resources - Technically Recoverable, Risked, By Product

Geological Resources Assessment Program-GRASP-Version 8.29.2005

The	Current	UAI	AAAAAH			
	is	for				
World	Level	-	World	Level	Resources	
Country	Level	-	UNITED	STATES	OF	AMERICA
Region	Level	-	MMS	-	ALASKA	REGION
Basin	**Level**	**-**	**NORTH**	**ALEUTIAN**	**BASIN**	

Basin Level Aggregation of Risked, Technically Recoverable Resources By Product (Province Aggregation ".out" file)

Volume Ordered (Play Aggregation Method)

RandomSeed = 511336

Number of Trials = 10000

Greater Than Percentage	BOE (Mboe)	Oil (Mbo)	Condensate (Mbc)	Solution Gas (Mmcfg)	Free (Gas Cap & Nonassociated) Gas (Mmcfg)
99	8,529.05	957.28	853.83	500.62	37,254.16
98	37,770.39	6,400.50	3,855.25	2,465.27	152,166.97
97	59,374.32	7,620.78	6,145.94	2,805.91	253,508.84
96	76,365.24	8,981.96	7,798.18	4,171.42	330,696.84
95	91,313.09	9,327.03	10,014.94	3,337.65	401,140.07
90	152,795.28	14,735.69	16,565.78	5,972.53	676,822.68
85	202,293.30	21,360.54	20,527.68	9,561.73	891,914.78
80	248,517.23	38,189.46	25,808.29	13,535.87	1,023,463.61
75	289,613.60	23,460.86	32,101.93	11,008.64	1,304,356.93
70	758,370.00	78,872.57	81,958.78	35,001.19	3,323,165.99
65	1,112,446.05	115,165.18	120,223.53	48,825.03	4,880,237.19
60	1,331,106.04	190,182.44	140,201.52	79,502.65	5,544,555.47
55	1,547,628.10	181,147.84	166,201.65	75,798.47	6,669,767.27
50	1,749,848.07	227,543.45	182,908.40	88,874.23	7,438,532.52
45	1,951,618.04	286,392.13	202,412.52	116,539.90	8,104,471.38
40	2,174,562.19	247,451.22	232,544.08	111,531.11	9,411,934.81
35	2,477,137.80	449,857.78	241,528.21	185,911.05	9,850,014.13
30	2,848,953.92	533,839.07	277,119.50	211,276.77	11,242,257.06
25	3,260,855.58	674,316.41	310,300.92	287,089.64	12,505,369.32
20	3,731,185.24	835,403.66	345,531.66	356,235.16	13,976,169.40
15	4,319,269.80	1,078,382.27	387,730.95	438,471.33	15,596,268.66
10	5,197,352.68	1,535,914.10	438,021.41	639,408.32	17,476,196.21
5	6,646,628.43	1,948,242.53	556,330.15	791,182.86	22,487,170.52
4	7,126,116.61	2,248,887.20	574,976.56	931,788.65	23,246,872.39
3	7,768,395.43	2,586,065.75	605,998.50	1,114,458.78	24,604,522.46
2	8,797,511.68	3,343,597.17	633,112.52	1,471,887.22	25,621,019.95
1	10,676,113.20	4,379,928.46	729,501.97	1,925,248.66	29,359,508.51
Mean	2,287,183.20	545,045.43	207,992.11	228,881.47	8,393,017.13
Rep	2,287,171.45	76,703.31	243,856.03	22,692.71	11,029,667.31
Min	0	0	0	0	0
Max	36,673,897.35	29,262,390.65	587,418.63	14,097,046.96	24,254,328.16

Table 4. Detailed report of ultimate technically recoverable resources (UTRR) by commodity for North Aleutian Basin Planning Area, as reported in province aggregation file by *GRASP* computer model.

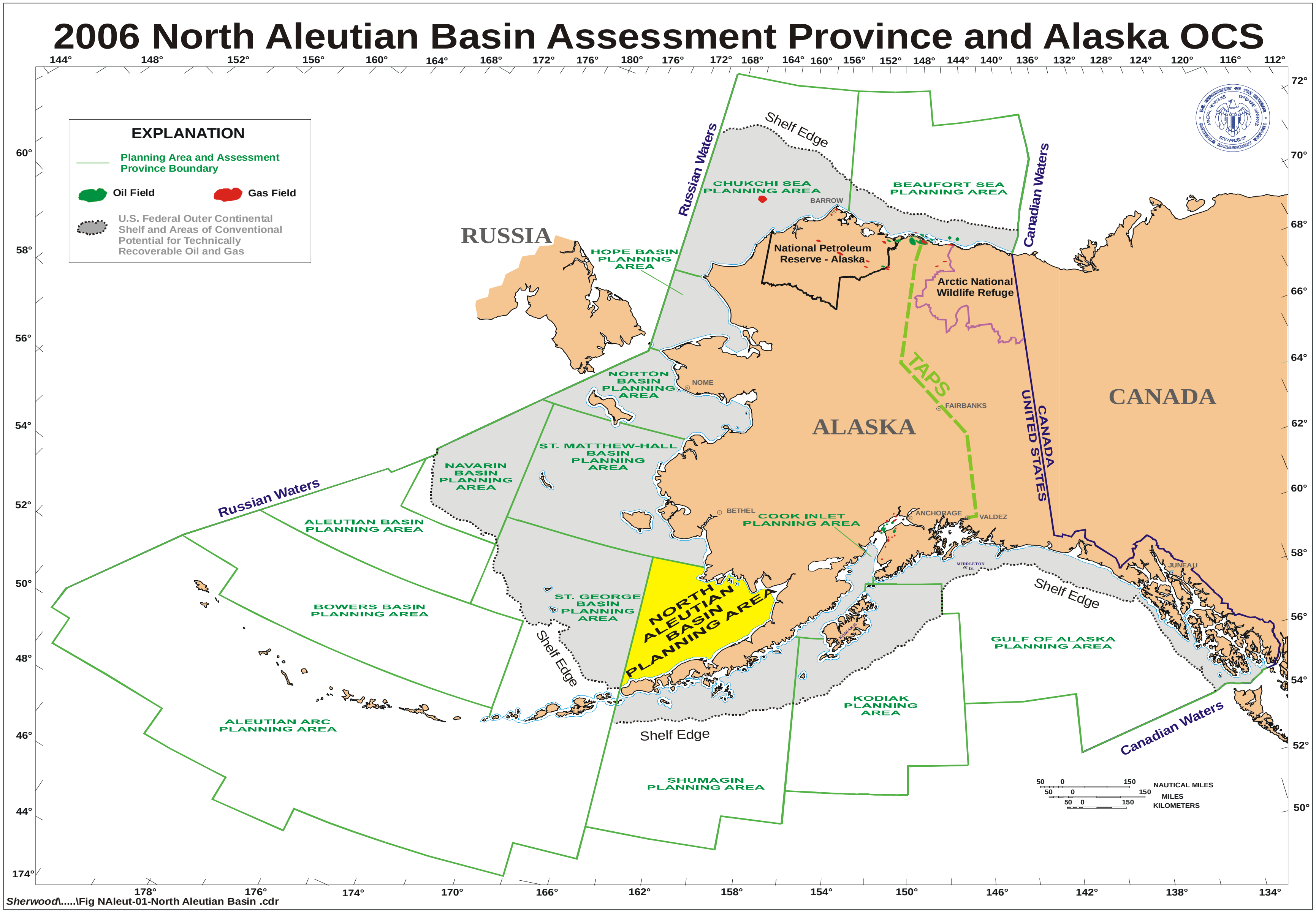


Figure 1. Location map for North Aleutian Basin OCS Planning Area and assessment province.

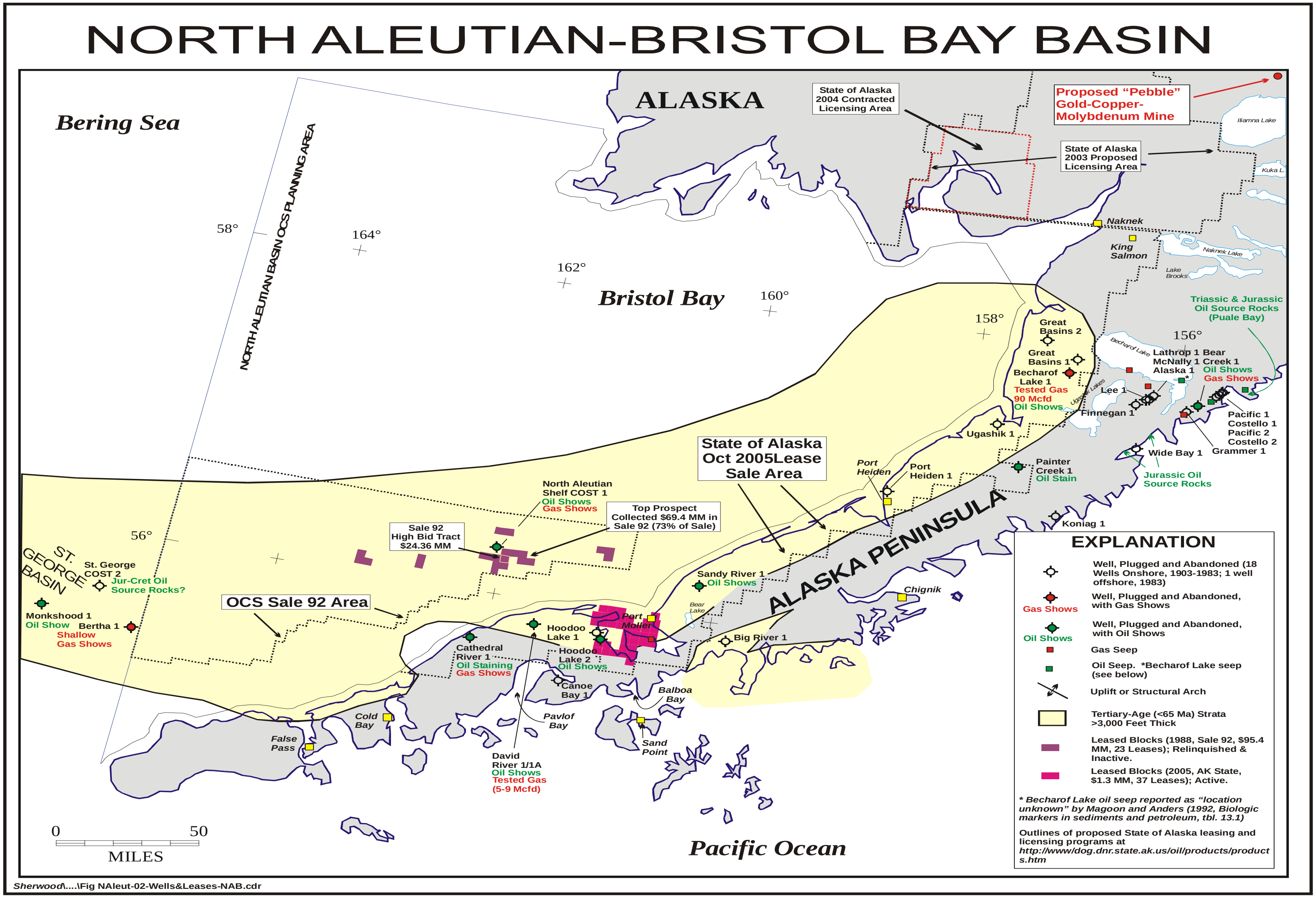


Figure 2. Regional map for North Aleutian basin, with well control, Sale 92 leases (now relinquished and inactive), State of Alaska leases near Port Moller (2005 sale), and regional distribution of Tertiary-age sedimentary rock.

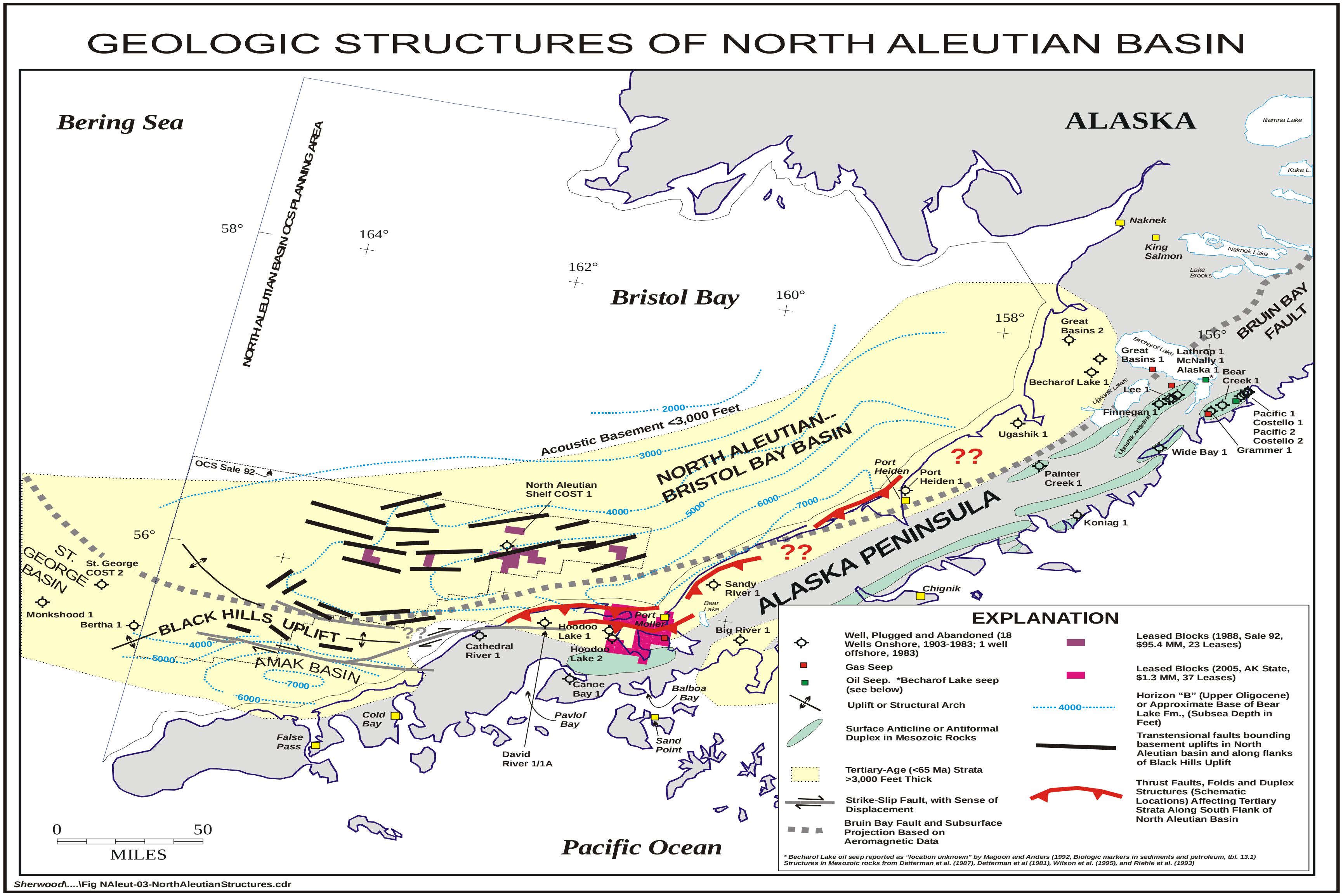


Figure 3. Principal geologic structures of the North Aleutian basin and contiguous areas, including: 1) transtensional faults and basement uplifts in western parts of the basin; 2) wrench-fault structures along the Black Hills uplift; and 3) fold/thrust belts along the southeast margin of the basin. The fold/thrust structures do not appear to extend into the Federal offshore (>3 miles).

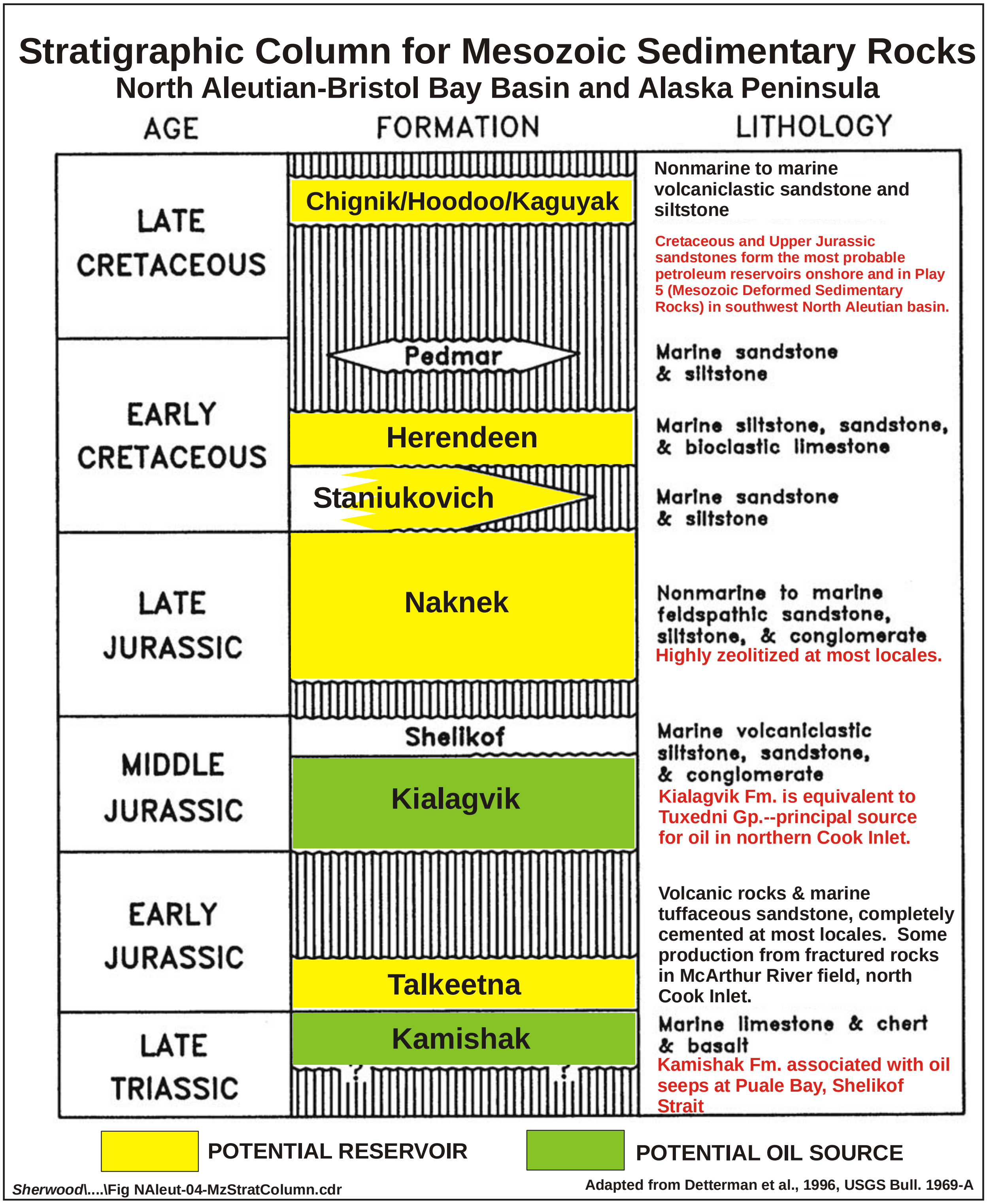


Figure 4. Mesozoic stratigraphy, Alaska Peninsula and substrate beneath southwest part of North Aleutian basin.

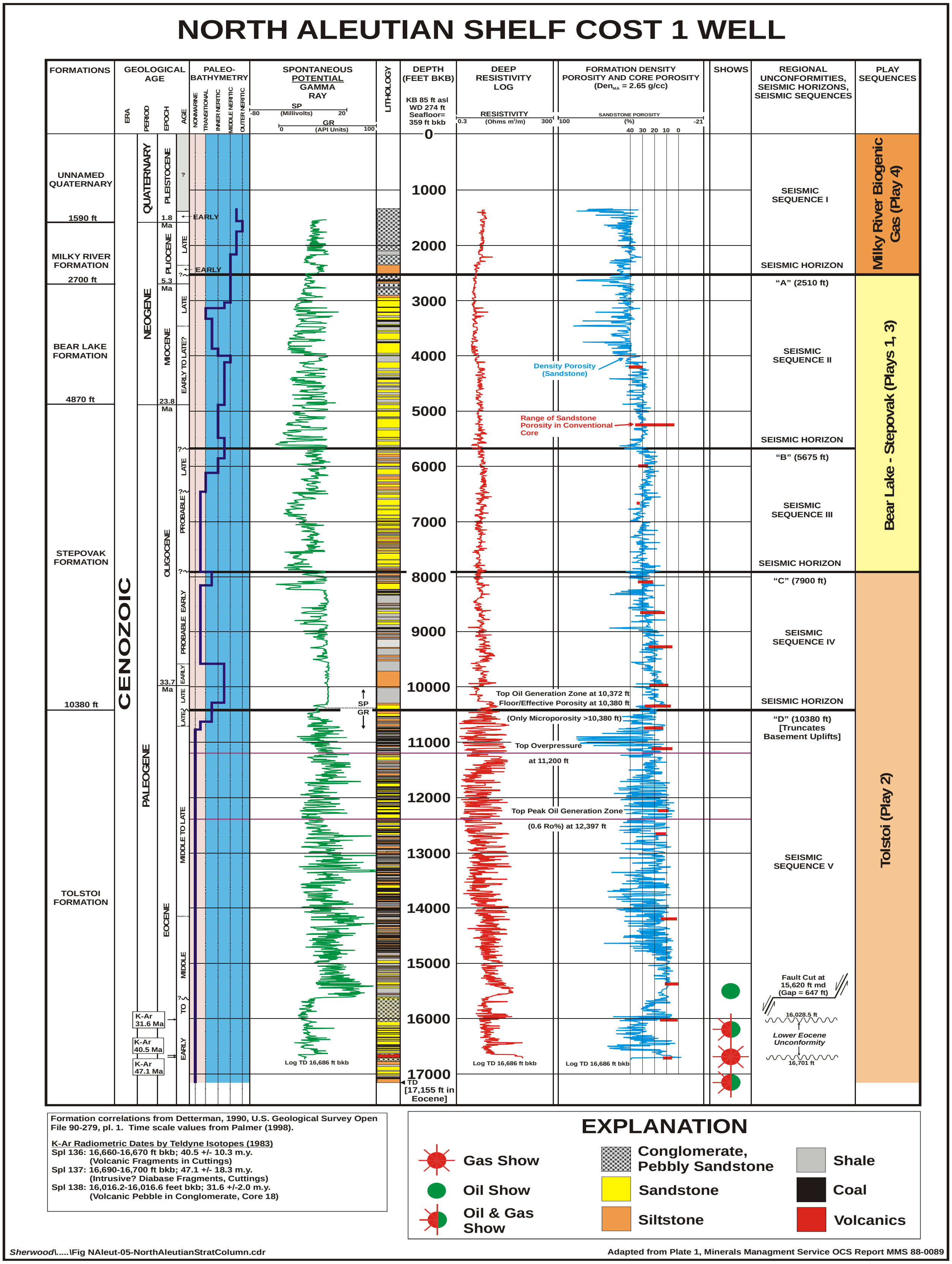


Figure 5. Wellbore stratigraphy, North Aleutian Shelf COST 1 stratigraphic test well, drilled by an industry consortium in 1983.

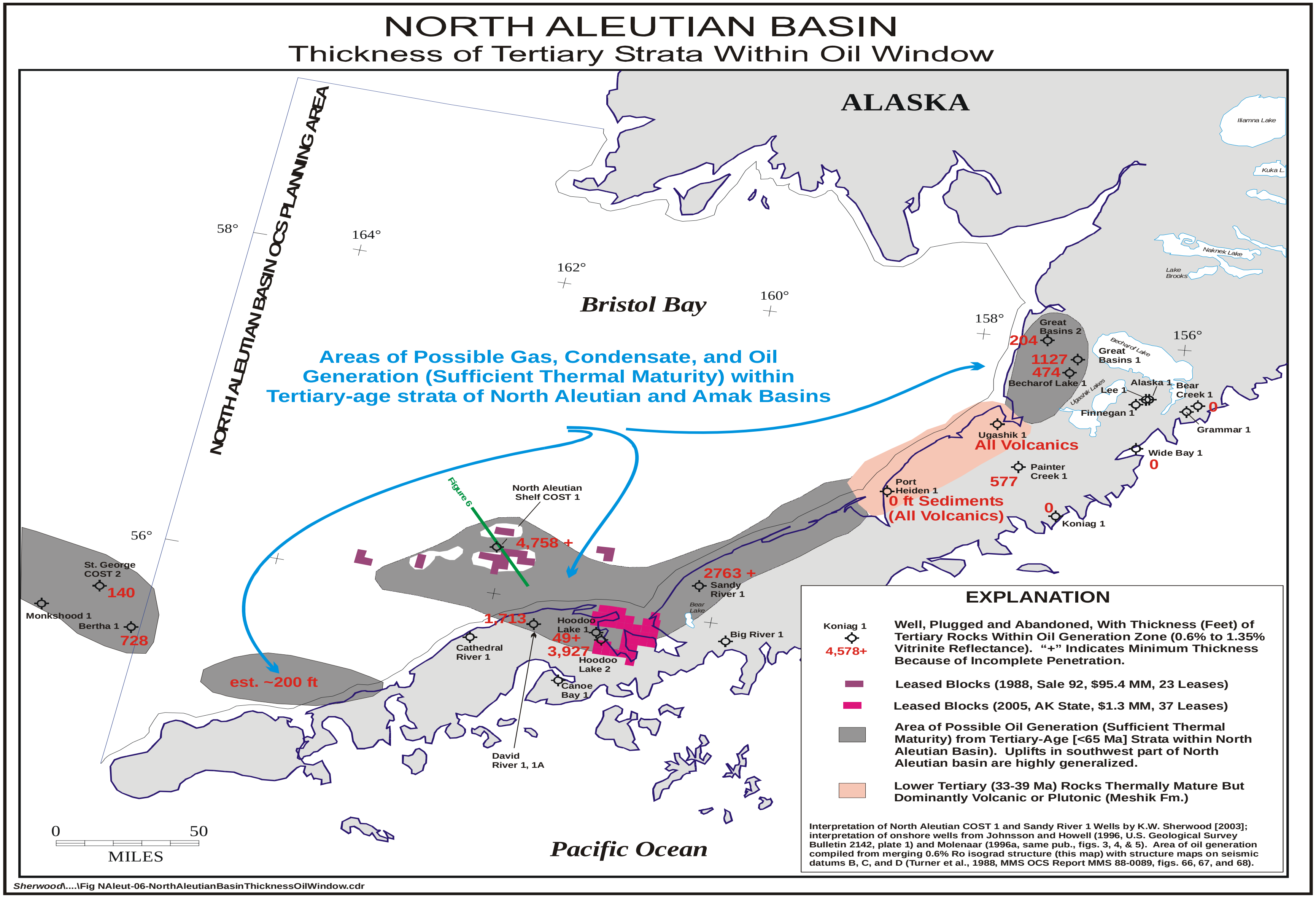


Figure 6. Isopach map for thickness of Tertiary-age rocks within oil generation zone (0.6% to 1.35% vitrinite reflectance) with probable areas of thermal maturity sufficient for oil generation within and beneath the North Aleutian basin.

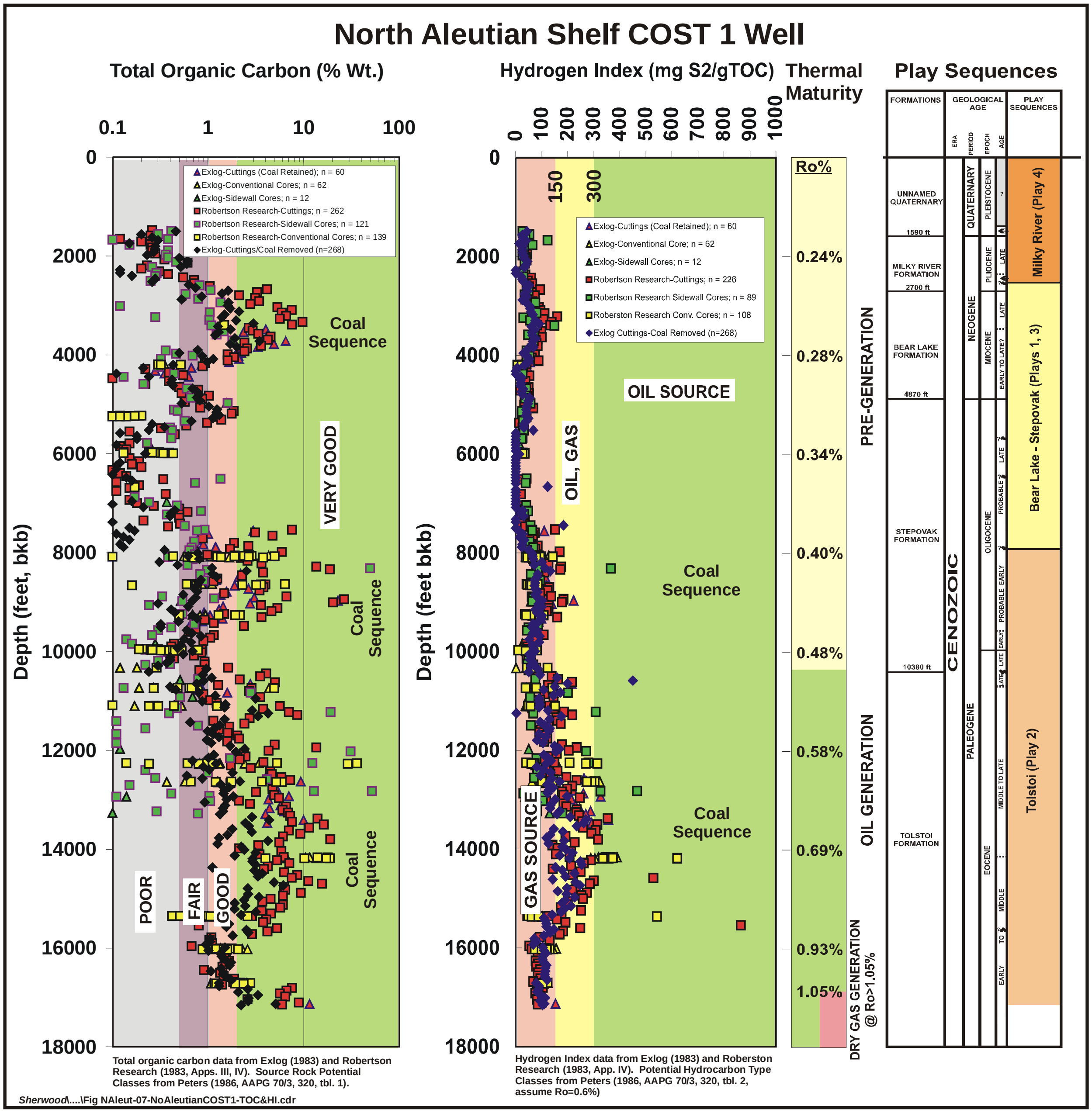


Figure 7. Generation potential (total organic carbon) and hydrocarbon type (hydrogen index) indicators for Tertiary rocks in the North aleutian Shelf COST 1 well.

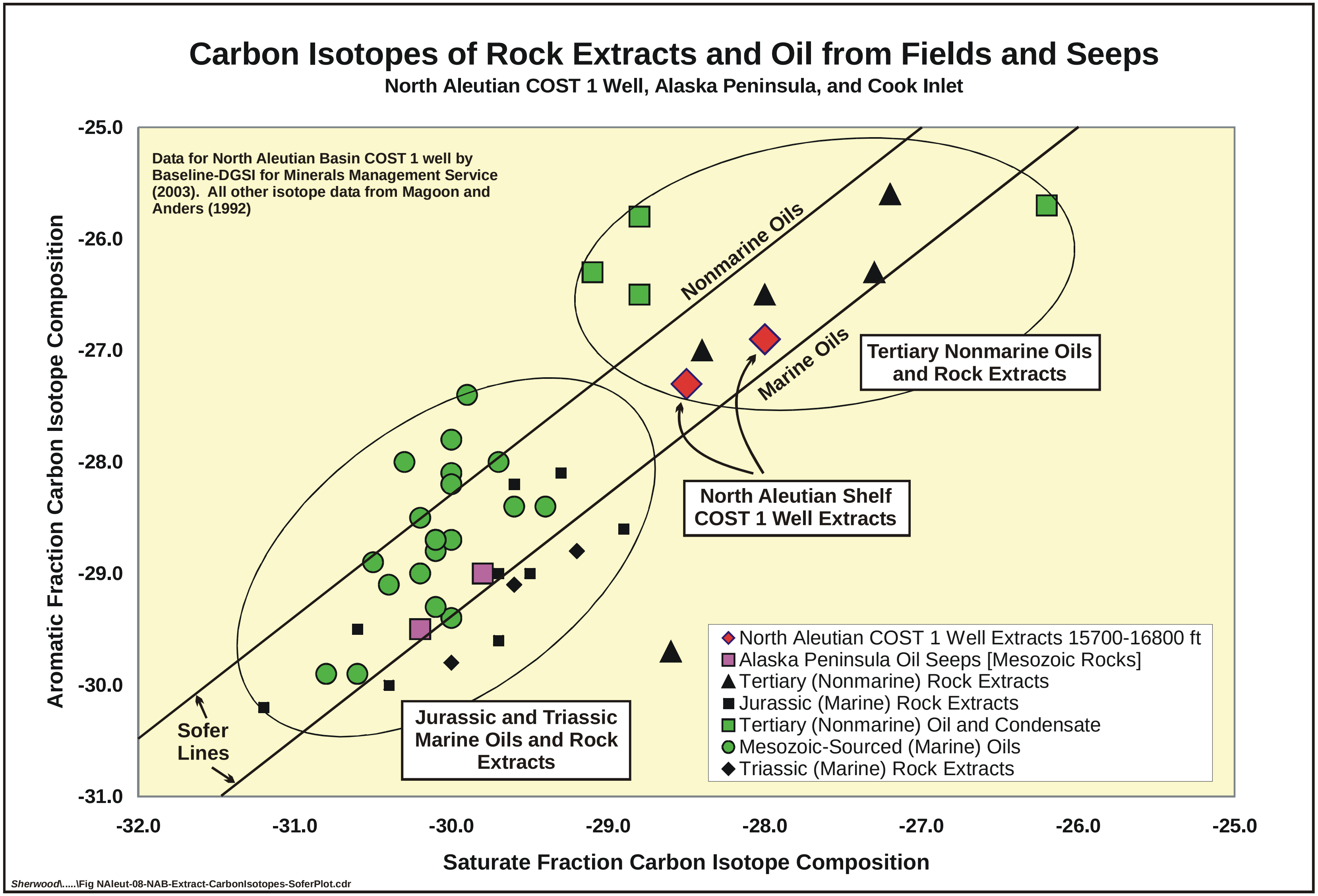
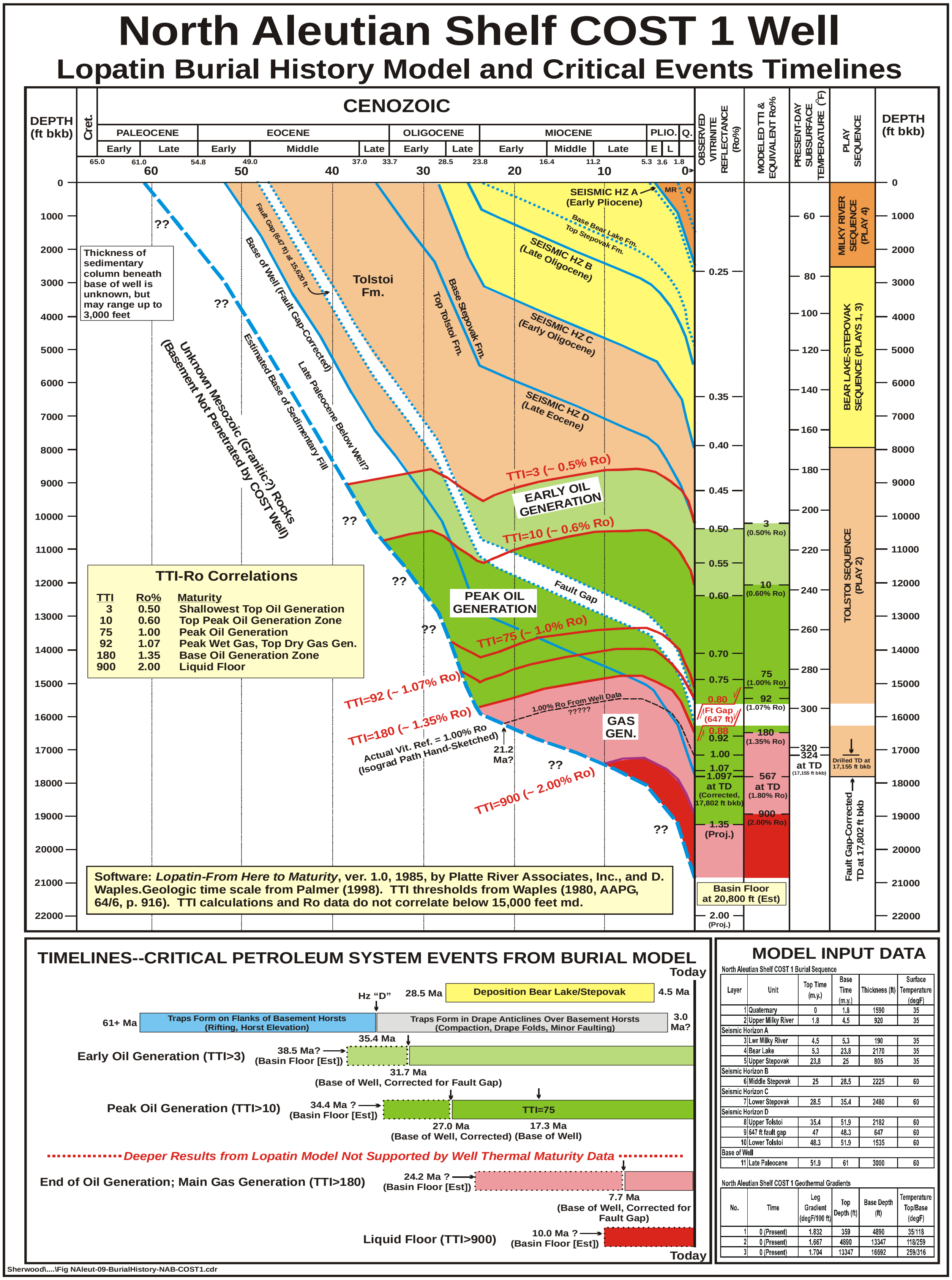


Figure 8. Carbon isotopes for aromatics and saturates, comparing North Aleutian Shelf COST 1 well extracts, Tertiary (nonmarine) extracts and oils, and Mesozoic (marine) extracts and oils. These data suggest that the oil shows in the North Aleutian Shelf COST 1 well originated from Tertiary nonmarine sources.



Layer	Unit	Top Time (m.y.)	Base Time (m.y.)	Thickness (ft)	Surface Temperature (degF)
1	Quaternary	0	1.8	1590	35
2	Upper Milky River	1.8	4.5	920	35
Seismic Horizon A					
3	Lwr Milky River	4.5	5.3	190	35
4	Bear Lake	5.3	23.8	2170	35
5	Upper Stepovak	23.8	25	805	35
Seismic Horizon B					
6	Middle Stepovak	25	28.5	2225	60
Seismic Horizon C					
7	Lower Stepovak	28.5	35.4	2480	60
Seismic Horizon D					
8	Upper Tolstoi	35.4	51.9	2182	60
9	647 ft fault gap	47	48.3	647	60
10	Lower Tolstoi	48.3	51.9	1535	60
Base of Well					
11	Late Paleocene	51.9	61	3000	60

North Aleutian Shelf COST 1 Geothermal Gradients

No.	Time	Leg Gradient (degF/100 ft)	Top Depth (ft)	Base Depth (ft)	Temperature Top/Base (degF)
1	0 (Present)	1.832	359	4890	35/118
2	0 (Present)	1.667	4890	13347	118/259
3	0 (Present)	1.704	13347	16692	259/316

Figure 9. Burial history plot for North aleutian COST 1 well, with timelines for critical petroleum system events.

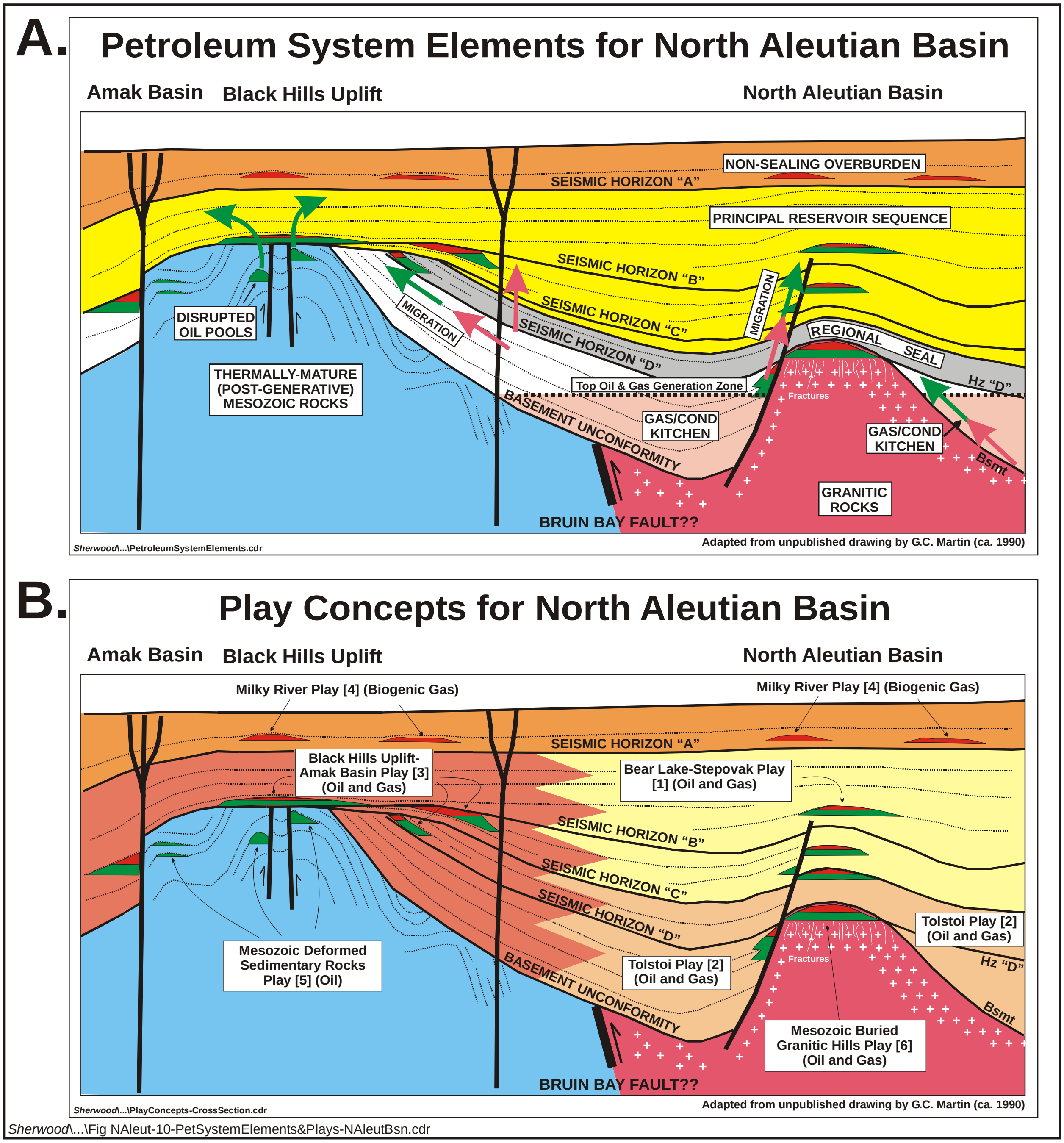


Figure 10. Schematic cross sections illustrating petroleum system elements and play concepts for North Aleutian Basin OCS Planning Area.

A) Petroleum system elements, including regional reservoir sequence floored by a regional seal and underlain by deep gas/condensate "kitchens" in grabens flanking uplifts. Petroleum generated in "kitchens" migrates to traps in shallow reservoir formations draped over basement uplifts via faults that pierce the regional seal. The Black Hills uplift may be reached by long-distance lateral migration of petroleum across highly faulted areas. Fault disruption of Mesozoic oil pools beneath the Black Hills uplift may release oil into overlying strata. Arrows show hypothetical migration paths for gas (red) and oil (green).

B) Six oil and gas plays defined for North Aleutian Basin OCS Planning Area, separated on the basis of reservoir character, structural style, and access to petroleum sources.

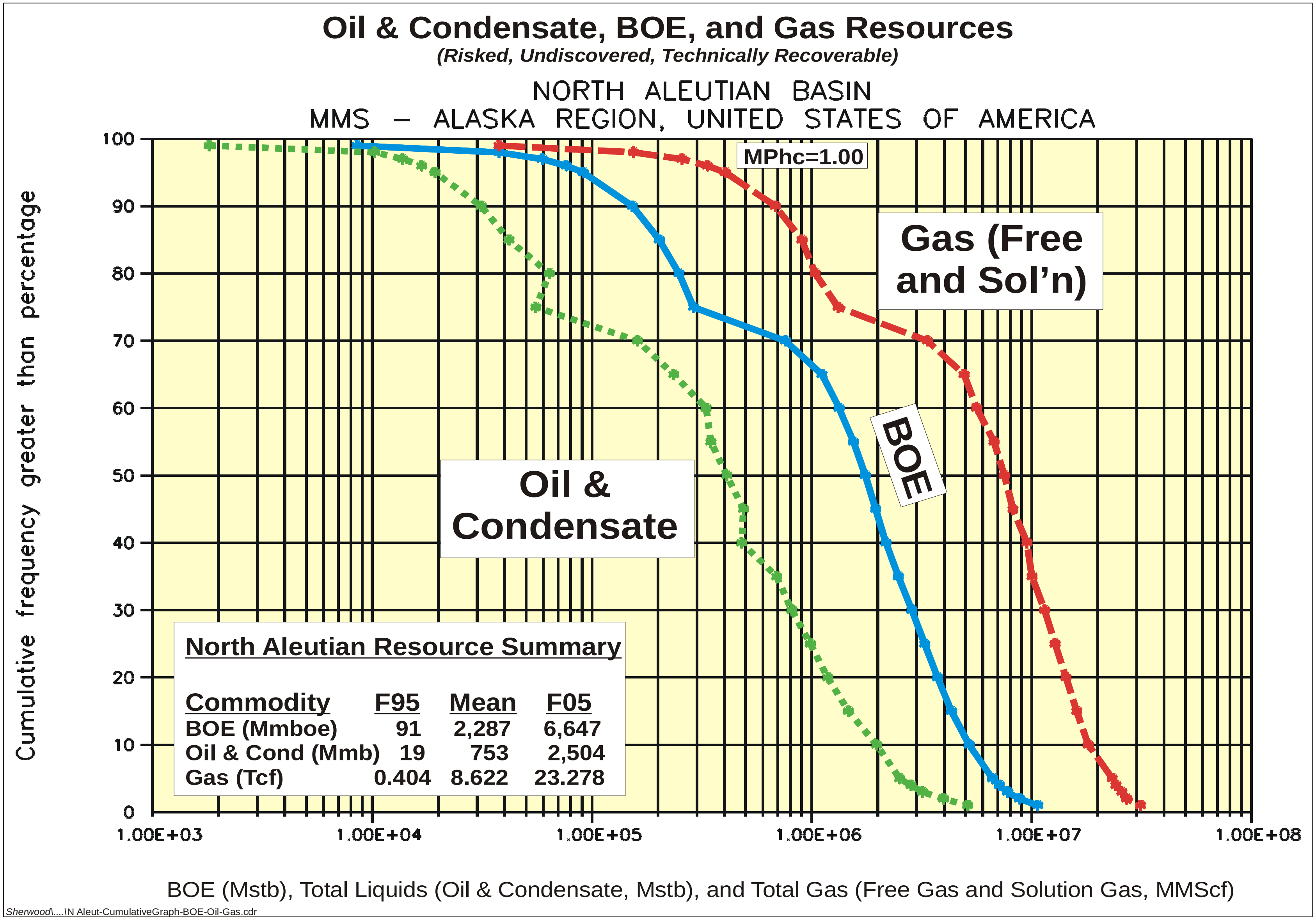


Figure 11. Cumulative probability plot for undiscovered, technically recoverable oil and gas resources for North Aleutian Basin Planning Area, 2006 assessment.