

North Aleutian Basin Play 2: Tolstoi (Eocene-Oligocene)

Geological Assessment

GRASP UAI: AAAAA HAC

Play Area: 10,890 square miles

Play Water Depth Range: 15-300 feet

Play Depth Range: 4,000-20,000 feet

Play Exploration Chance: 0.1404

Play 2, Tolstoi (Eocene-Oligocene), North Aleutian Basin OCS Planning Area, 2006 Assessment, Undiscovered Technically-Recoverable Oil & Gas			
Assessment Results as of November 2005			
Resource Commodity (Units)	Resources *		
	F95	Mean	F05
BOE (Mmboe)	91	568	1,293
Total Gas (Tcfg)	0.404	2.501	5.693
Total Liquids (Mmbo)	19	123	280
Free Gas** (Tcfg)	0.401	2.476	5.640
Solution Gas (Tcfg)	0.003	0.025	0.053
Oil (Mmbo)	9	62	139
Condensate (Mmbc)	10	61	141

* Risked, Technically-Recoverable
 ** Free Gas Includes Gas Cap and Non-Associated Gas
 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

Play 2, the “Tolstoi” play, is the second most important play in the North Aleutian Basin OCS Planning Area, with 25% (568 Mmboe) of the Planning Area energy endowment (2,287 Mmboe). The overall assessment results for play 2 are shown in [table 1](#). Oil and gas-condensate liquids form 22 percent of the hydrocarbon energy endowment of play 2. [Table 5](#) reports the

detailed assessment results by commodity for play 2.

[Table 3](#) summarizes the volumetric input data developed for the *GRASP* computer model of North Aleutian basin play 2. [Table 4](#) reports the risk model used for play 2. The location of play 2 is shown in [figure 1](#).

The Tolstoi play sequence corresponds in the North Aleutian Shelf COST 1 well to the lower part of the Stepovak Formation and the entire Tolstoi Formation. The play sequence ranges in age from early Eocene to early Oligocene. In onshore areas, rocks correlative to play 2 were penetrated by 5 wells (Becharof Lake 1, Great Basins 1, Great Basins 2, Hoodoo Lake 2, and David River 1/1A wells). Offshore, in eastern St. George Basin, correlative rocks were penetrated by the St. George Basin COST 2 well. The North Aleutian Shelf COST 1 well is the most important point of control for the Tolstoi play sequence in the North Aleutian basin.

Gas is pooled in several Tolstoi Formation intervals in the Becharof Lake 1 well, where flow tests of separate intervals recovered gas at rates ranging from 10 to 50 mcfg/d, or a total of 90 mcfg/d for all three zones. In the Becharof Lake 1 well, cuttings headspace gas carbon isotopes (AOGCC, 1985) for the Tolstoi Formation range from -32.8 to -43.9 ($\delta^{13}\text{C}$ [PDB]), indicating thermogenic gas. Gas was recovered in flow tests from two intervals in the Tolstoi Formation at rates of 5 to 10 Mcfgpd (with 300-400 bwpd) in the David River 1/1A well. Gas shows were associated with Tolstoi Formation coals in the North Aleutian Shelf COST 1 well as well as in the 5 Tolstoi penetrations onshore.

Oil shows were noted in the Tolstoi Formation in the North Aleutian Shelf COST 1, Becharof Lake 1, Hoodoo Lake 2, and David River 1/1A wells).

Most of the oil and gas resources of play 2 are associated with simple anticlines draped over basement uplifts, or, in truncation traps (against faults and unconformities) on the flanks of basement uplifts. Mapped traps range up to 53,000 acres in closure area. The upper part of the Tolstoi play sequence (lower part of Stepovak Formation) passes over the crests of basement uplifts. In the North Aleutian Shelf COST 1 well, the upper part of the Tolstoi play sequence contains porous and permeable sandstones that are sparse (236 feet net, or 10% of interval) and thin (maximum = 43 feet). A regional shale seal in the lower part of the Stepovak Formation is prominent within the upper part of the Tolstoi play sequence. The lower part of the Tolstoi play sequence is involved in fault- and stratigraphic-truncation traps on the flanks of basement uplifts. Sandstones are abundant in the lower Tolstoi play sequence (1,910 feet net, 30% of sequence) in the North Aleutian Shelf COST 1 well, but are thin-bedded (maximum = 57 feet) and impermeable (diagenesis of volcanic particles has resulted in collapse of framework grains; 84% of core samples have <10 md permeability). No oil source rock formation has been identified in the North Aleutian basin but coals and shales with Type III (coal-like) organic matter are abundant and could form sources for both biogenic and thermogenic gas, condensate, and minor oil. For this reason, play 2 is modeled as gas-prone. Oil shows were encountered in the interval from 15,300 to 16,800 feet (corresponds to 0.78% to 1.04% Ro) in the North Aleutian Shelf COST 1 well. Carbon isotopes on extracts from the show interval correlate to extracts and oils from Tertiary-age rocks in northern

Cook Inlet as opposed to extracts and oils from Mesozoic-age source rocks on the Alaska Peninsula and beneath Cook Inlet. These data suggest that Mesozoic oil source beds do not underlie North Aleutian basin in the area of play 2. The hypothetical petroleum system for play 2 assumes that gas and minor liquids migrating out of Tertiary rocks in the deep parts of North Aleutian basin rise along faults bounding basement uplifts to charge shallow reservoir beds draped over uplifts or truncated on uplift flanks.

The major risk factors for play 2 relate to: **1) reservoir** (thin sandstones are porous in the upper Tolstoi play sequence but are impermeable in the lower Tolstoi play sequence); and **2) source adequacy** (no attractive source formation in known Tertiary-age rocks; Mesozoic rocks beneath play 2 are pervasively invaded by plutons and cannot form a source for petroleum).

A maximum of 44 hypothetical pools is forecast by the integration of the risk model and the prospect numbers model for play 2. These 44 pools range in mean conditional (un-risked) recoverable volumes from 7 Mmboe (pool rank 44) to 208 Mmboe (pool rank 1). Pool rank 1 ranges in possible conditional recoverable volumes from 61 Mmboe (F95) to 467 Mmboe (F05), or, in the gas case, from 0.34 Tcfge (F95) to 2.62 Tcfge (F05). [Table 2](#) shows the conditional sizes of the 10 largest pools in play 2.

Play 2, Tolstoi, North Aleutian Basin OCS Planning Area, 2006 Assessment, Conditional BOE Sizes of Ten Largest Pools			
Assessment Results as of November 2005			
Pool Rank	BOE Resources *		
	F95	Mean	F05
1	61	208	467
2	34	124	248
3	22	90	182
4	16	71	146
5	13	59	122
6	11	51	107
7	9	45	96
8	8	41	88
9	7	38	82
10	6	35	79

* 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

In the computer simulation for play 2, a total of 61,326 “simulation pools” were sampled for size. These simulation pools can be grouped according to the USGS size class system in which sizes double with each successive class. Pool size class 12 contains the largest share (18,963, or 31%) of simulation pools (conditional, technically recoverable BOE resources) for play 2. Pool size class 12 ranges from 64 to 128 Mmboe. The 5 largest simulation pools for play 2 fall within pool size class 16, which ranges in size from 1,024 to 2,048 Mmboe (or 5.8 to 11.5 Tcfge). [Table 6](#) reports statistics for the simulation pools developed in the GRASP computer model for play 2.

GRASP Play Data Form (Minerals Management Service-Alaska Regional Office)

Basin: North Aleutian Basin
 Play Number: 2
 Play UAI Number: AAAAA HAC

Assessor(s): K.W. Sherwood, D. Comer, J. Larson
 Play Name: Tolstoi (Eocene-Oligocene)

Date: December 2004

Play Area: 10,890 mi² (7 million acres)
 Reservoir Thermal Maturity: 0.30%-1.65% Ro

Play Depth Range: 4,000 to 20,000 feet (mean = 12,000 ft)
 Expected Oil Gravity: 35° API
 Play Water Depth Range: 15-300 feet (mean = 250 ft)

POOLS Module (Volumes of Pools, Acre-Feet)

Fractile	F100	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Prospect Area (acres)- Model Input*	6787 (act)		6567 (fit)		11169	15925/9790			28028				52653
Prospect Area (acres)- Model Output**	1518	5490	6647	9321	13549	15555/8547	19702	23776	27111	33179	36000	38000	52353
Fill Fraction (Fraction of Area Filled)	0.16	0.28	0.3	0.34	0.4	0.41/0.10	0.48	0.51	0.53	0.6	0.65	0.69	1
Productive Area of Pool (acres)	455	2031	2509	3631	5447	6442/3960	8173	10082	11572	14470	16000	17000	31312
Pay Thickness (feet)	31	49	53	60	69	71/17	80	86	91	98	107	113	171

* model fit to prospect area data in *BESTFIT*

** output from @RISK after aggregation with fill fraction

MPRO Module (Numbers of Pools)

Input Play Level Chance	1
Output Play Level Chance*	0.9904

Prospect Level Chance	0.1404
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Exploration Chance	0.1404
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* First Occurrence of Non Zero Pools As Reported in PSUM Module

Risk Model	Play Chance	Petroleum System Factors	Prospect Chance
		Minor gas pools tested (90 Mcfg/d) in Becharof Lake 1 well	
		Reservoir (impermeable through most of sequence)	0.216
		Source (mainly Tertiary coals and Type III shales)	0.65

Fractile	F99	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Numbers of Prospects in Play	16	20	23	30	40	43.65/19.72	51	60	65	75	90	100	200
Numbers of Pools in Play	1	2	2	4	6	6.13/3.60	8	9	11	12	15	18	44

Zero Pools at F99.06

Minimum Number of Pools	1 (F99.00)	Mean Number of Pools	6.13	Maximum Number of Pools	44
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POOLS/PSRK/PSUM Modules (Play Resources)

Fractile	F100	F95	F90	F75	F50	Mean/Std. Dev.	F25	F15	F10	F05	F02	F01	F00
Oil Recovery Factor (bbl/acre-foot)	25	57	75	113	178	203/118	266	322	364	430	480	510	803
Gas Recovery Factor (Mcfg/acre-foot)	18	351	433	630	921	997/497	1285	1509	1657	1933	2100	2300	3200
Gas Oil Ratio (Sol'n Gas)(cf/bbl)	56	162	195	267	376	426/220	531	638	723	871	1073	1100	1110
Condensate Yield (bbl/Mmcfg)	1	14	17	21	25	25/17	29	32	34	35	37	39	50

Pool Size Distribution Statistics from *POOLS* (1,000 BOE): μ (mu)= 11.079 σ^2 (sigma squared)= 0.828 Random Number Generator Seed= 668,076

BOE Conversion Factor (cf/bbl)	5620	Probability Any Pool Contains Both Oil and Free Gas (Gas Cap)	0.1
Probability Any Pool is 100% Oil	0.1	Fraction of Pool Volume Gas-Bearing in Oil Pools with Gas Cap	0.9
Probability Any Pool is 100% Gas	0.8		

Table 3. Input data for North Aleutian basin play 2, 2006 assessment.

GRASP - Geologic and Economic Resource Assessment Model - PSUM Module Results

Minerals Management Service - Alaska OCS Region
 GRASP Model Version: 8.29.2005)
 Computes the Geologic Resource Potential of the Play

Play UAI: AAAAAHAC **Play No. 2**

World	Level	-	World	Level	Resources
Country	Level	-	UNITED STATES		OF AMERICA
Region	Level	-	MMS		ALASKA REGION
Basin	Level	-	NORTH ALEUTIAN		BASIN
Play	Level	-	Play		2 Tolstoi Fm. (Eocene/Paleocene)
Geologist	Sherwood	/	Comer	/	Larson

Remarks: 2005 Assessment
 Run Date & Time: Date 19-Sep-05 Time 14:07:43

Summary of Play Potential

Product	MEAN	Standard Deviation
BOE (Mboe)	568,290	395,110
Oil (Mbo)	61,795	103,820
Condensate (Mbc)	61,389	45,180
Free (Gas Cap & Nonassociated) Gas (Mmcf)	2,476,000	1,778,300
Solution Gas (Mmcf)	25,468	47,513

10000 (Number of Trials in Sample)
 0.9904 (MPhc [Probability] of First Occurrence of Non-Zero Resource)
 Windowing Feature: used

Empirical Probability Distributions of the Products

Greater Than Percentage	BOE (Mboe)	Oil (Mbo)	Condensate (Mbc)	Free (Gas Cap & Nonassociated) Gas (Mmcf)	Solution Gas (Mmcf)
100	0	0	0	0	0
99.99	0	0	0	0	0
99	8,529	957	854	37,254	501
95	91,313	9,327	10,015	401,140	3,338
90	152,800	14,736	16,566	676,820	5,973
85	202,290	21,361	20,528	891,910	9,562
80	248,520	38,189	25,808	1,023,500	13,536
75	289,610	23,461	32,102	1,304,400	11,009
70	329,450	36,536	34,516	1,437,400	14,785
65	369,140	36,695	40,797	1,624,500	14,591
60	406,520	51,571	43,941	1,724,200	23,685
55	449,820	51,904	49,642	1,935,900	21,375
50	492,540	53,987	52,365	2,150,300	20,099
45	537,690	62,498	57,387	2,323,600	24,458
40	584,360	59,474	63,106	2,571,400	23,751
35	633,610	62,240	68,665	2,798,700	26,501
30	694,240	64,037	75,519	3,088,800	28,563
25	764,980	84,186	83,493	3,323,300	33,530
20	840,410	93,682	90,457	3,644,700	43,567
15	931,730	105,510	99,330	4,037,100	48,038
10	1,072,100	133,200	113,950	4,583,200	52,730
8	1,141,400	145,060	120,540	4,864,600	57,111
6	1,231,400	148,240	130,040	5,298,200	58,476
5	1,293,200	139,440	140,810	5,640,200	52,824
4	1,367,200	123,940	150,500	6,084,800	56,563
2	1,604,200	199,550	170,570	6,854,700	80,494
1	1,841,500	228,970	198,460	7,861,700	85,313
0.1	3,160,100	263,120	377,640	14,082,000	76,469
0.01	4,209,200	691,650	436,720	17,115,000	198,810
0.001	4,294,200	613,150	430,690	18,115,000	152,220

Table 5. Assessment results by commodity for North Aleutian basin play 2, 2006 assessment.

Classification and Size				Pool Count Statistics			Pool Types Count		Mixed Pool Range		Oil Pool Range		Gas Pool Range		Total Pool Range		Pool Resource Statistics (MMBOE)				
Class	Min (MMBOE)	Max (MMBOE)	Pool Count	Percentage	Trial Average	Trials w/Pool Avg	Mixed Pool	Oil Pool	Gas Pool	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Total Resource	Average Resource
1	0.0312	0.0625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
2	0.0625	0.125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
3	0.125	0.25	2	0.003261	0.0002	0.000202	0	0	2	0	0	0	0	1	1	1	1	1	1	0.137452	0.224087
4	0.25	0.5	3	0.004892	0.0003	0.000303	0	0	3	0	0	0	0	1	1	1	1	1	1	0.301342	0.496114
5	0.5	1	34	0.055441	0.0034	0.003433	1	0	33	1	1	0	0	1	1	1	1	1	1	0.545680	0.955496
6	1	2	105	0.171216	0.0105	0.010601	2	3	100	1	1	1	1	1	1	1	1	1	1	1.024939	1.980937
7	2	4	310	0.505495	0.031	0.031297	12	13	285	1	1	1	1	1	2	1	2	1	2	2.013871	3.996668
8	4	8	944	1.539315	0.0944	0.095305	68	80	796	1	2	1	2	1	3	1	3	1	3	4.008479	7.993170
9	8	16	2646	4.314646	0.2646	0.267138	225	333	2088	1	2	1	2	1	4	1	5	1	5	8.000040	15.997020
10	16	32	8004	13.05156	0.8004	0.808077	780	819	6405	1	3	1	3	1	6	1	7	1	7	16.001224	31.997773
11	32	64	16546	26.9804	1.6546	1.670469	1662	1633	13251	1	4	1	4	1	14	1	15	1	15	32.000627	63.994934
12	64	128	18963	30.921633	1.8963	1.914488	1920	1780	15263	1	4	1	5	1	11	1	11	1	11	64.003268	127.995753
13	128	256	10866	17.718422	1.0866	1.097022	1033	1123	8710	1	3	1	4	1	8	1	10	1	10	128.004998	255.980052
14	256	512	2633	4.293448	0.2633	0.265825	252	352	2029	1	2	1	2	1	4	1	4	1	4	256.041355	511.094438
15	512	1024	265	0.432117	0.0265	0.026754	23	39	203	1	1	1	1	1	2	1	2	1	2	512.167367	1009.363000
16	1024	2048	5	0.008153	0.0005	0.000505	0	1	4	0	0	1	1	1	1	1	1	1	1	1050.289000	1415.393000
17	2048	4096	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
18	4096	8192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
19	8192	16384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
20	16384	32768	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
21	32768	65536	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
22	65536	131072	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
23	131072	262144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
24	262144	524288	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
25	524288	1048576	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
Not Classified			0	0	0	0	Below Class	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000
Totals			61326	100	6.1326	6.191419	Above Class	0	0	0	0	0	0	0	0	0	0	0	0	0.000000	0.000000

Number of Pools not Classified: 0	Min and Max refer to numbers of pools of the relevant size class that occur within any single trial in the simulation.	Min and Max refer to aggregate resources of the relevant size class that occur within any single trial in the simulation.
Number of Pools below Class 1: 0		
Number of Trials with Pools: 9905		

Table 6. Statistics for simulation pools created in computer sampling run for North Aleutian basin play 2, 2006 assessment.

PLAY 2: TOLSTOI FM. (Eocene-Oligocene)

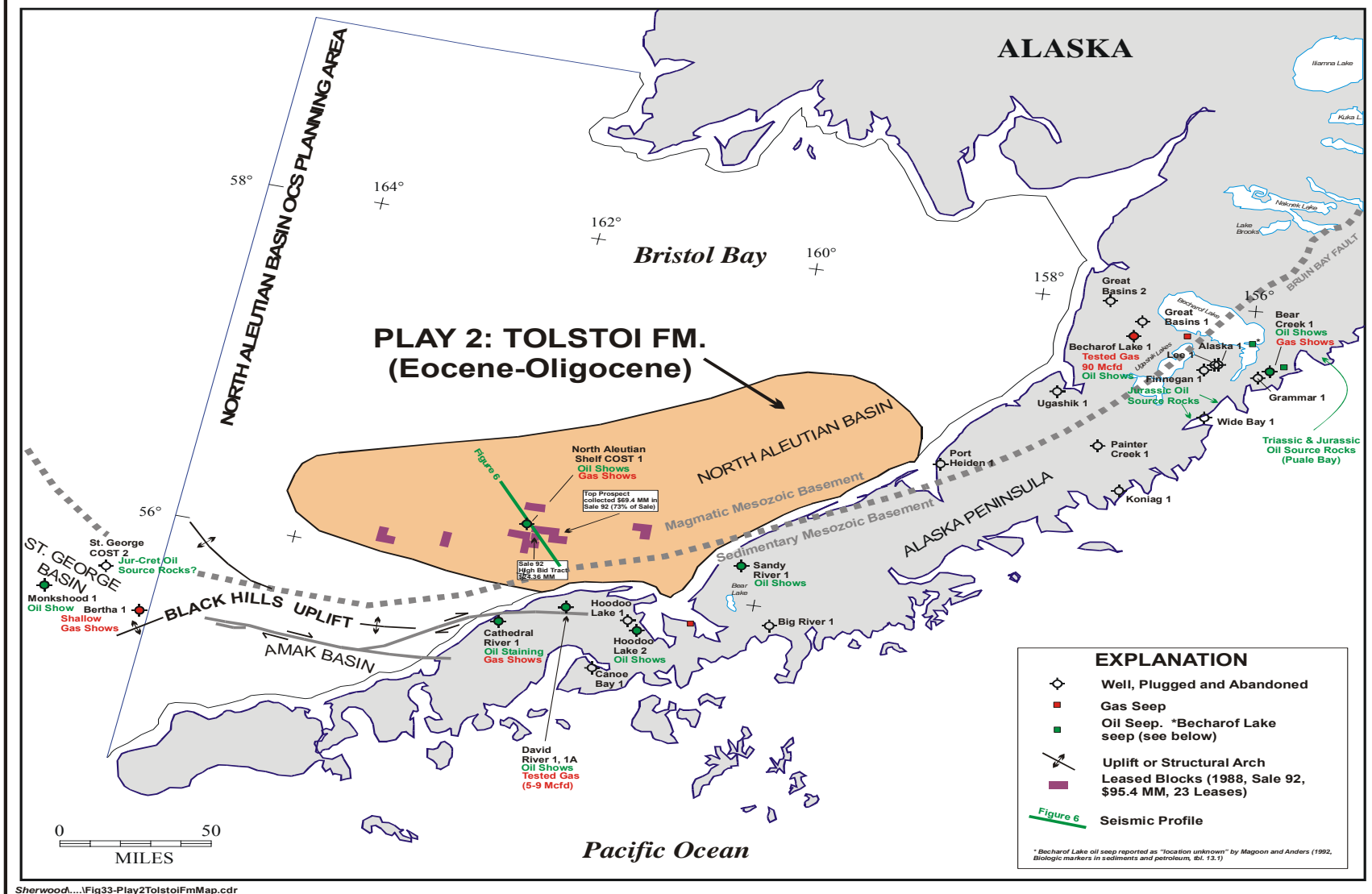


Figure 1. Map location of North Aleutian basin play 2, 2006 assessment.