Division of Geological & Geophysical Surveys

PRELIMINARY INTERPRETIVE REPORT 2005-1

Bristol Bay and Alaska Peninsula 2004: Fieldwork and Sample Analyses Compilation Report

by
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February 2005

Released by

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
Division of Geological & Geophysical Surveys
3354 College Rd.
Fairbanks, Alaska 99709-3707

$2.00

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Introduction

This preliminary report is based on the 2004, twenty-two day, two-phase, Bristol Bay-Alaska Peninsula field program (Figure 1). The program's first phase focused on source rock potential of the Mesozoic section (Figure 2; Figure 4). The second phase focused on reservoir potential and stratigraphic architecture of Tertiary rocks (Figure 3; Figure 5). Data included here are rock sample details and field station locations, headspace gas analyses, whole oil geochemistry, organic geochemistry, total organic carbon, kerogen typing, porosity and permeability, and inorganic geochemistry. Separate reports from the Alaska Division of Geological & Geophysical Surveys (DGGS) summarize the megafossil data (Blodgett, in preparation) and the measured stratigraphic sections (Ridgway and Finzel, in preparation). Both bear on surface to subsurface stratigraphic correlations.

This report is relevant to hydrocarbon-resources and exploration models within the state Division of Oil and Gas's Bristol Bay area-wide lease sales for 2005 and beyond, and is available on the DGGS website (http://www.dggs.dnr.state.ak.us). The Division of Oil and Gas (DOG) website (http://www.dog.dnr.state.ak.us) includes a variety of Bristol Bay and Alaska Peninsula information including geology, well locations and details, cross section, area-wide lease sale maps and information, and public seismic data.

Field-based results presented here are part of the *Bristol Bay basin petroleum reservoir characterization, source rock potential, and fossil fuel resources program (2004-2007)*, funded by the U.S. Department of Energy through the Arctic Energy Technology Development Laboratory at the University of Alaska Fairbanks, DGGS, and DOG. Geologists participating are: Rocky Reifenstuhl (DGGS; program head), Dave Shafer (DOG), Tim Ryherd (DOG), Don Brizzolara (DOG), Robert Blodgett (consulting megafossil paleontologist), Mark Myers (DOG), Emily Finzel (DGGS), Ken Ridgway (Purdue University), and Paul McCarthy (University of Alaska Fairbanks; non-field collaborator). The manuscript was reviewed by Marwan Wartes of DGGS.

The first phase of this project included 11 days (May 24 to June 4, 2004) of helicopter-supported fieldwork in the Puale Bay and Wide Bay areas, northeast Alaska Peninsula (Figures 1 and 2). Base camp facilities were at Grizzly Skins Lodge near the Kajulik River and Becharof Lake. Our primary goal for this field investigation was to better understand the source rock potential and stratigraphy of the Mesozoic (Jurassic and Triassic) section (Figure 4), and sample oil seeps for geochemical characterization.

The second phase was 11 days (August 23 to September 2, 2004) of helicopter-supported fieldwork in the Port Moller, Herendeen Bay, and Bear Lake area, Bristol Bay (Figures 1 and 3). Base camp facilities were at Bear Lake Lodge on Bear Lake. This portion of the project focused on the reservoir potential of the Tertiary strata (Figure 5), particularly the Miocene Bear Lake and Pliocene Milky River formations.

Outcrop field stations and samples are all from the Mesozoic and Tertiary part of the stratigraphic section (Figures 4 and 5). Mesozoic samples from the northeast side of the Alaska Peninsula are from the Kamishak (Triassic), Talkeetna (Lower Jurassic), Kialagvik (Middle Jurassic), Shelikof (Middle Jurassic), and Naknek (Upper Jurassic) formations. Mesozoic samples from the greater Port Moller area are from the Herendeen Limestone (Lower Cretaceous) and the Coal Valley Member (Upper Cretaceous) of the Chignik Formation. Tertiary outcrops in the greater Port Moller area include the Tolstoi (Eocene), Stepovak (Oligocene), Bear Lake (Miocene), and Milky River (Pliocene) Formations.

This report is intended as a timely public release of a wide variety of analytical data on outcrop samples collected in the first field season of this project. Each of the tables in this report is listed below with some pertinent background information.

Discussion of Data

Table 1 – List of Sample Locations and Analyses Performed: This is a compilation of basic field station information, including latitude and longitude, rock unit, and the analysis performed.

Table 2 – Headspace Gas Analysis of Gas Seep Sample: Results from one gas sample (04RR139A) from the hot springs in Herendeen Bay, southwest of Port Moller (139 on Figure 3). Results indicate more than 99 percent methane. Gas bubbles strongly through the hot springs pool, which is located in a vegetated point of land on the west side of Port Moller Bay. Scheduled for the 2005 field season is a sampling program that will collect additional gas for isotopic analyses aimed at constraining the source of the gas generation.

Tables 3a through 3d – Whole Oil Geochemical Analyses of Oil Seep Sample: Whole oil analyses are from one sample of the oil and gas seep near Oil Creek (04RR14; 14 on Figure 2). Detailed analyses indicate a highly biodegraded oil. The seep flows an estimated one-half barrel per day into a small pool of water in a tundra and muskeg area some 100 meters from the main Oil Creek waters. Most of the light hydrocarbons evaporate prior to the oil seep reaching Oil Creek. A 150-meter-wide delta-shaped fan has been deposited over time; it consists of extremely viscous, tarry hydrocarbon. To the southeast and downstream 500 to 700 meters on Oil Creek, very small quantities of hydrocarbon flow directly from fractures in the very fine sandstone of the Shelikof Formation. These minor seeps produce an oily sheen on some creek waters. Locally, there are minor occurrences in the outcrops of sandstone that have a dark opaque matrix that appear to be oil charged. Importantly, the hydrocarbon typing analyses of the oil seep sample from Oil Creek is in part correlative with the Kamishak Formation source rock analyses.

Table 4 – Total Organic Carbon, Pyrolysis Analysis of 15 Outcrop Samples: Rocks analyzed range from the Triassic Kamishak Formation from the northeast point of land of Puale Bay to the Miocene Bear Lake Formation from Port Moller. One Kamishak Formation limestone yields 2.38 percent total organic carbon (TOC). This rock is from a carbonate section that includes biohermal deposits. A similar muddy limestone from the same Kamishak Formation section yields 1.12 percent TOC. More detailed source rock sampling of the Kamishak Formation will be conducted during the 2005 field program. The Middle Jurassic Kialagvik Formation samples (3) range from 0.54 to 0.81 percent TOC. The Kialagvik Formation also will be sampled systematically during the 2005 field program. One sample was collected from the Snug Harbor Member of the Naknek Formation (Upper Jurassic) and yields 2.19 percent TOC. This locality is 1 kilometer west of the southwest arm of Becharof Lake. Based on the silty claystone and shale lithologies of this section, which yielded relatively high TOC, additional sampling is scheduled during the 2005 season. The Oligocene Stepovak Formation sample is from a section southeast of Bear Lake, and consists of interbedded sandstone, siliceous siltstone and black coaly material. The sample yields 9.54 percent TOC. The high carbon content is due to coaly fragments in the sediment. A back-bay or lagoonal depositional environment is interpreted for these sediments. The carbon content in the Stepovak Formation and Bear Lake Formation samples (0.21 and 0.08 percent TOC), combined with low hydrogen index values, suggest that the kerogen is most likely gas prone woody material. The remaining samples in the table are from marine or deep marine depositional environments (see Figure 1 for kerogen typing analyses of 12 samples). More detailed sampling and analyses will more closely constrain kerogen typing during 2005.

Figure 6 - Kerogen Type Determination, 2004 Bristol Bay outcrop samples: Shows the hydrocarbon generating kerogen from 12 selected rocks. The background discussion of the rock samples and their formations are in Table 4 notes above. The three oil-prone samples on the graph are from the Kamishak Formation and from oil-charged sandstone from the Snug Harbor Member of the Naknek Formation. Importantly, the hydrocarbon typing analyses of the oil seep sample from Oil Creek (Table 3) is in part correlative with the Kamishak Formation source rock analyses.

Table 5 – Porosity and Permeability Analyses of 81 Outcrop Samples: This table is a list, arranged from youngest to oldest, of the nine rock units which range from Pliocene to Middle Jurassic; all are outcrop samples.

Figure 7 – Porosity and Permeability of Outcrop Samples (undifferentiated): This is a plot showing porosity and permeability results for 59 outcrop samples. Approximately half of the samples are from the Mesozoic section. Mesozoic samples are uniformly low in both porosity and permeability, with the exception of four samples from the Chisik Member of the lower Naknek Formation. These Mesozoic rock units were sampled in an effort to obtain a

more complete petrophysical outline of the entire stratigraphic succession on the Alaska Peninsula. The majority of the sampled intervals were never considered to be potential reservoir targets. Rather, they were the focus of source rock potential or depositional environment studies, and outcrop petrophysics samples were collected for comprehensiveness. Consequently, the porosity and permeability values are quite low for two of the three Middle and Late Jurassic units (Kialagvik Formation, Shelikof Formation, and for some of the Naknek Formation). When considering all samples, only 10 percent have more than 1 millidarcy permeability, and these have corresponding porosity values ranging from 5 to 37 percent. About 30 percent of the 81 samples have permeability greater than 0.10 millidarcy, with porosity in the 5 to 15 percent range. Despite poor permeability (<0.10 millidarcy), these rocks can be considered viable gas reservoirs. It's important to note that several outcrops of the Chisik Conglomerate Member of the basal Naknek Formation, the Bear Lake Formation, and the Milky River Formation were too unconsolidated to process for petrophysical analyses. Considering that the Bear Lake Formation is expected to be the reservoir in many published hydrocarbon play models, this is an important aspect that the data alone do not portray.

Figure 8 – Porosity and Permeability of Outcrop Samples (by formation): This plot summarizes the petrophysical analyses for the nine rock units that range from Pliocene to Middle Jurassic. The Pliocene Milky River Formation samples from the Port Moller area have the best reservoir quality, followed by the Chisik Member of the Naknek Formation, and the Bear Lake Formation. Several samples plotted from the Bear Lake, Milky River, and Chisik Conglomerate formations do not convey that several outcrops of these units were too unconsolidated for obtaining core samples. That aside, the vast majority of Bear Lake samples have good porosity but their corresponding permeability is low to poor. Petrographically, the low permeability is apparently due to alteration products of volcanic rock fragments and pore-clogging clays. These diagenetic processes have reduced the pore connectivity in many samples. Milky River Formation sample values are the best with a maximum of 3,500 millidarcies and 32 percent porosity. The Pliocene Milky River Formation is relatively high in the stratigraphic section, and in many published hydrocarbon play models, is considered a less likely reservoir than the underlying Miocene Bear Lake Formation.

Table 6 – Inorganic Geochemistry: Analyses of one sample (04RR20C) of the Upper Cretaceous Chisik Conglomerate Member of the Naknek Formation reveals that this dense, magnetic, oil-charged sandstone contains 23 percent, by weight, magnetic minerals. The Chisik Member on the southeast side of Deer Mountain, northwest of Wide Bay (Figure 2), is a succession of sandstone and conglomerate. The channelized, non marine- to marginal-marine, very-coarse grained sandstone is very dark gray to black, poorly sorted, with subrounded grains, and has a slightly greasy feel. The sandstone is nearly 17 percent iron (Fe_2O_3 + FeO), with only 1.2 percent titanium oxide, suggesting that magnetite, not ilmenite, is the dominant magnetic mineral. The same sandstone has 13.9 percent porosity and 0.22 millidarcy permeability. The concentrated magnetic minerals were likely derived from the intermediate volcanic and plutonic rocks of the Jurassic arc system. Abundant plutonic and volcanic cobbles in the interbedded conglomerate support this interpretation.

This preliminary report is significant in that it documents oil-charged sandstone outcrops in the Chisik Member of the lower Naknek Formation on the east side of Deer Mountain, and south of Puale Bay on the ridge northeast of Teressa Creek (04RR20C; number 20 on Figure 2). Our goal with this raw data release is to inform the energy industry and general public of new hydrocarbon exploration-pertinent information for the Mesozoic section in the study area.

Field observations and organic geochemical analyses yield new, modern information that bear on Mesozoic reservoir characteristics, stratigraphy, source rock total organic carbon (TOC), liquid hydrocarbon typing from a seep between Oil Creek and Ugashik Creek (Figure 2), and distribution of stratigraphic units in the Puale Bay and Wide Bay areas. This ongoing Bristol Bay-Alaska Peninsula program is scheduled for additional fieldwork at the end of August 2005 in the Bear Lake area, northeast of Port Moller. During these two weeks we will address the reservoir potential, stratigraphic architecture, and structural framework of the Tertiary stratigraphic section. These Tertiary rocks, particularly the Miocene Bear Lake Formation, are potential reservoirs in the Bristol Bay region.

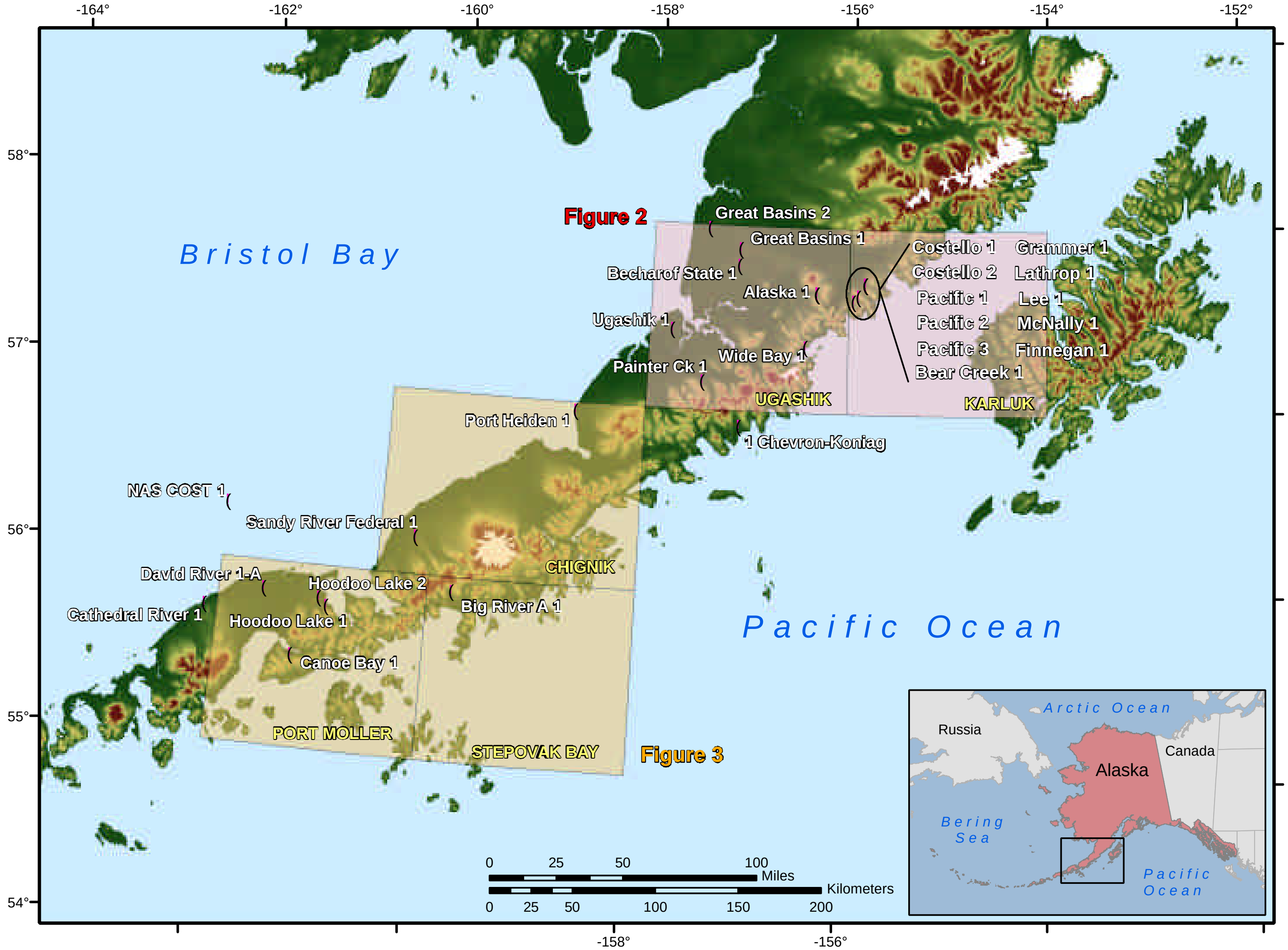

Figure 1. Field area location map of Alaska Peninsula and Bristol Bay, showing locations of figures 2 and 3, wells drilled in the area, and quadrangle index.

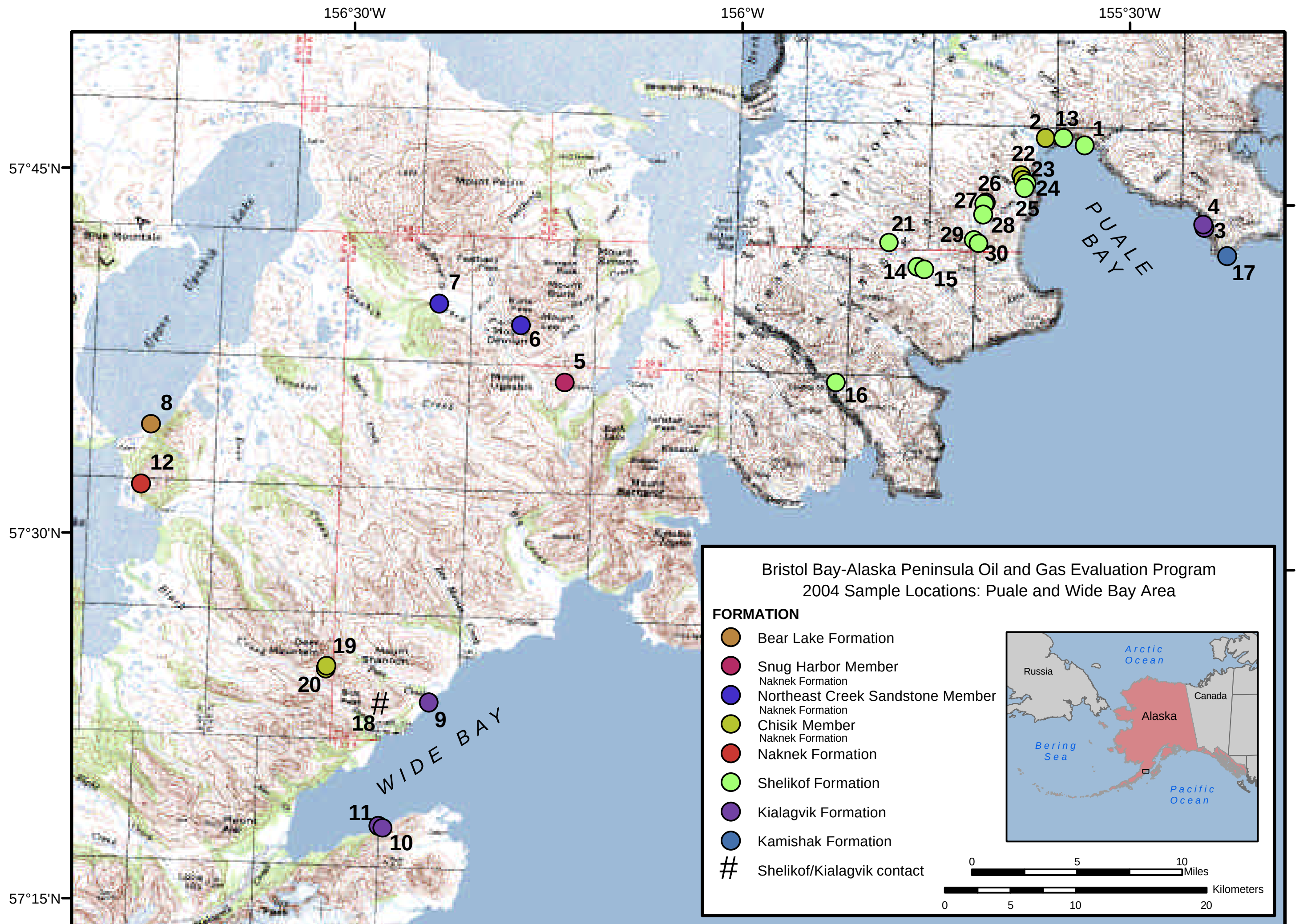

Figure 2. Location map for Rocky Reifenstuhl's sample locations, Phase 1, Mesozoic section. Labels are the last two digits of sample identifications listed in the text and tables.

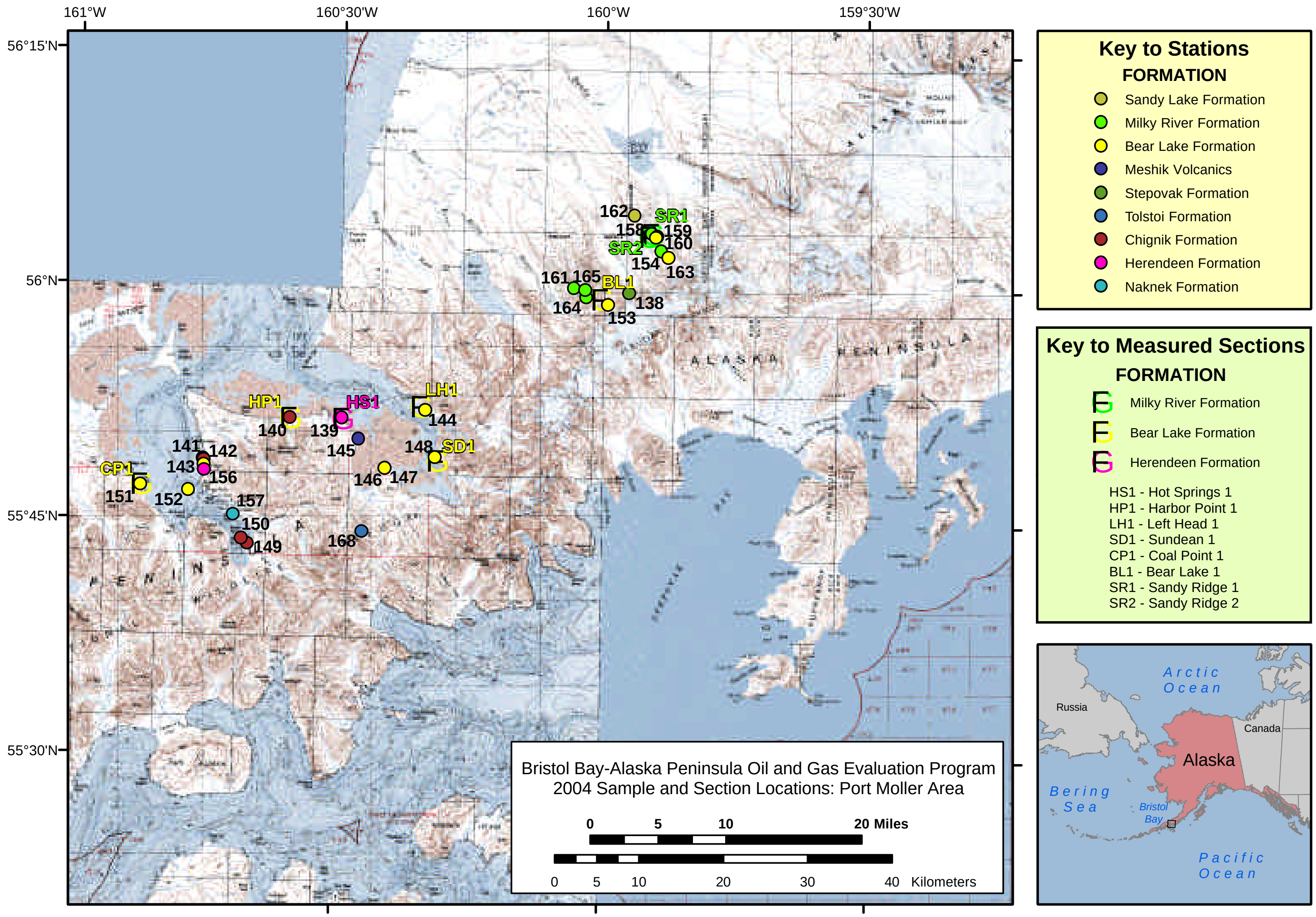

Figure 3. Location map for Rocky Reifenstuhl's sample locations, Phase 2, Tertiary section. Labels are the last two digits of sample identifications listed in the text and tables, or abbreviations for measured sections.

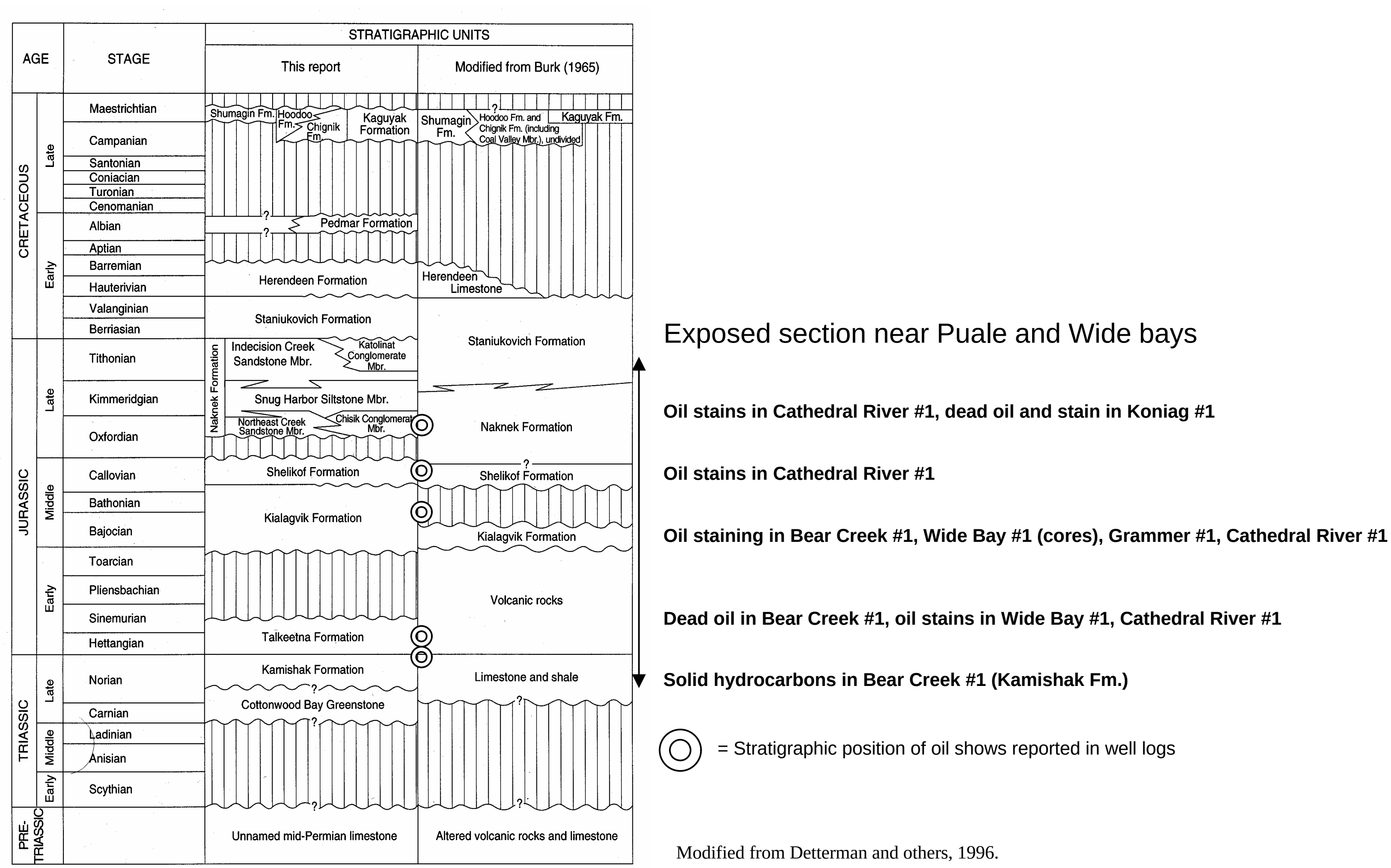

Figure 4. Generalized Mesozoic stratigraphic section in the Alaska Peninsula and Bristol Bay area. Circles indicate stratigraphic position of oil shows reported in well logs and literature.

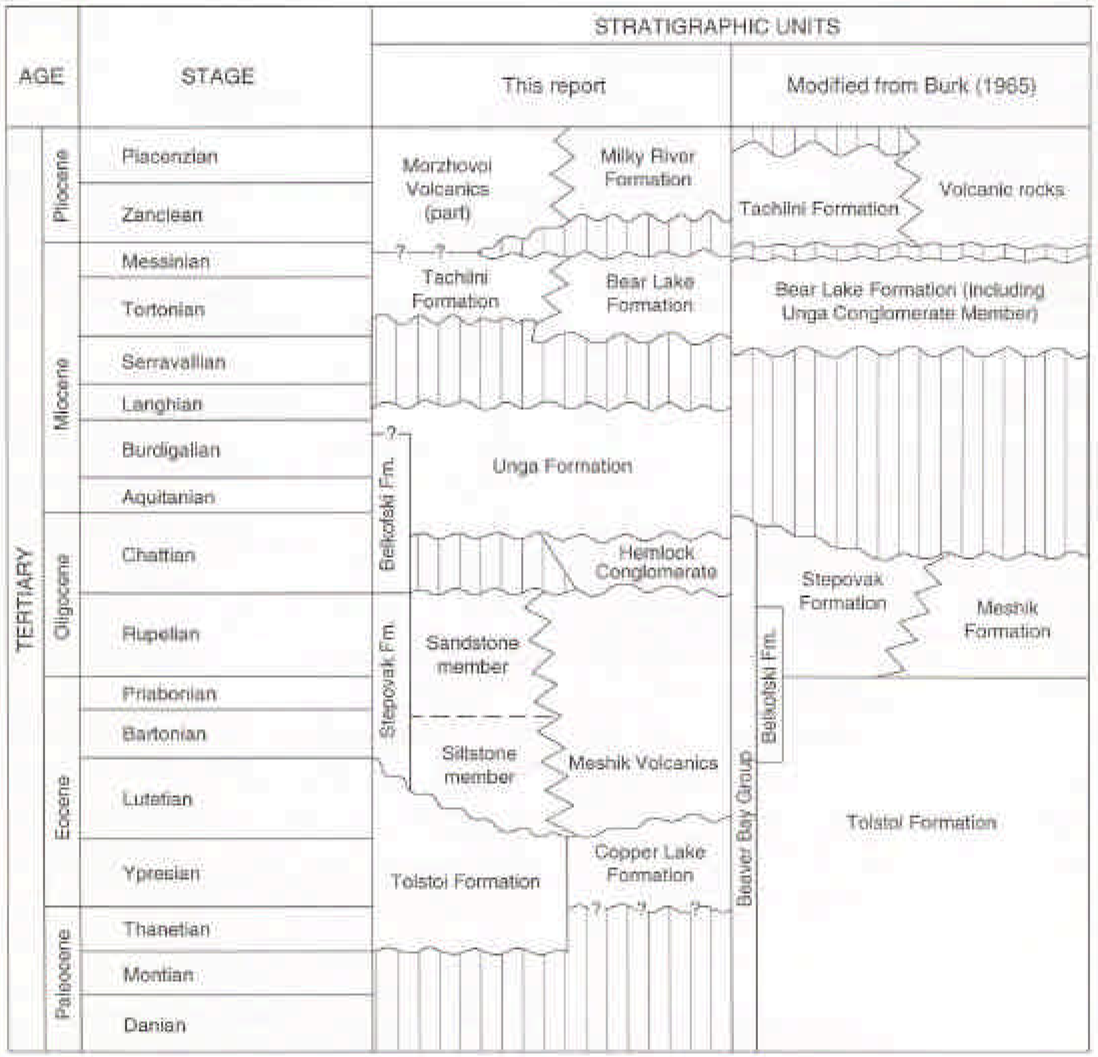

Figure 5. Generalized Tertiary stratigraphic section in the Alaska Peninsula and Bristol Bay area. From Detterman and others, 1996.

Sample ID	Formation	Analysis	Latitude	Longitude	Sample ID	Formation	Analysis	Latitude	Longitude	Sample ID	Formation	Analysis	Latitude	Longitude
04RR154B	Milky River	PP	56.04404	-159.89347	04RR138	Stepovak	PP	55.99835	-159.95333	04RR7B	Naknek	PP	57.66677	-156.37852
04RR158C	Milky River	PP	55.06233	-159.91165	04RR138D	Stepovak	TOC	55.99835	-159.95333	04RR7D	Naknek	PP	57.66677	-156.37852
04RR158G	Milky River	PP	55.06233	-159.91165	04RR155B	Tolstoi	PP	55.48712	-161.47603	04RR7B	Naknek	PP	57.66677	-156.37852
SR2-6	Milky River	PP	56.06010	-159.91490	04RR155B	Tolstoi	PP	55.48712	-161.47603	04RR7D	Naknek	PP	57.66677	-156.37852
SR2-89.5	Milky River	PP	56.06010	-159.91490	04RR168B	Tolstoi	PP	55.74076	-160.45229	04TJR09	Naknek	PP	57.53558	-156.75181
SR1-3.5	Milky River	PP	56.06151	-159.91139	04RR141B	Chignik	PP	55.81506	-160.75445	04TJR4G	Naknek	TOC	57.61553	-156.21453
04RR140B	Bear Lake	TOC	55.86046	-160.59232	04RR142A	Chignik	TOC	55.81390	-160.75302	04DS10A	Shelikof	TOC	57.79258	-155.57119
04RR140C	Bear Lake	PP	55.86046	-160.59232	04RR142B	Chignik	PP	55.81390	-160.75302	04DS10B	Shelikof	TOC	57.79258	-155.57119
04RR140E	Bear Lake	TOC	55.86046	-160.59232	04RR149B	Chignik	PP	55.72546	-160.66745	04DS11	Shelikof	TOC	57.62118	-155.86644
04RR148B	Bear Lake	PP	55.82106	-160.75302	04RR150B	Chignik	PP	55.73109	-160.67883	04RR13B	Shelikof	PP	57.79295	155.58232
04RR152C	Bear Lake	PP	55.78132	-160.78056	04RR151C	Chignik	PP	55.78552	-160.87170	04RR13C	Shelikof	TOC	57.79295	-155.58232
04RR153D	Bear Lake	PP	55.98597	-159.99297	041RR139D	Herendeen	PP	55.86117	-160.49365	04RR14[2]	Shelikof	WOGC	57.70178	-155.76631
04RR163C	Bear Lake	PP	56.03701	-159.87989	04RR139A[1]	Herendeen	HSG	55.86117	-160.49365	04RR15B	Shelikof	PP	57.70040	-155.75723
04RR8B	Bear Lake	PP	57.57675	-156.74220	04RR139C	Herendeen	PP	55.86117	-160.49365	04RR15D	Shelikof	PP	57.70040	-155.75723
04RR8D	Bear Lake	PP	57.57675	-156.74220	04RR156B	Herendeen	PP	55.80278	-160.75218	04RR15G	Shelikof	PP	57.70040	-155.75723
04RR8E	Bear Lake	PP	57.57675	-156.74220	04RR156C	Herendeen	TOC	55.80278	-160.75218	04RR16B	Shelikof	PP	57.62120	-155.86636
CP1-11	Bear Lake	PP	55.78596	-160.87172	04RR156D	Herendeen	PP	55.80278	-160.75218	04RR18B	Shelikof	PP	57.39030	-156.43261
CP1-138	Bear Lake	PP	55.78596	-160.87172	HS1-12	Herendeen	PP	55.85998	-160.49368	04RR18D	Shelikof	PP	57.39030	-156.43261
CP1-178	Bear Lake	PP	55.78596	-160.87172	HS1-16	Herendeen	PP	55.85998	-160.49368	04RR1D	Shelikof	PP	57.78810	-155.55492
CP1-26	Bear Lake	PP	55.78596	-160.87172	HS1-2.5	Herendeen	PP	55.85998	-160.49368	04RR28B	Shelikof	PP	57.73912	-155.68372
CP1-38	Bear Lake	PP	55.78596	-160.87172	HS1-5.5	Herendeen	PP	55.85998	-160.49368	04RR29A	Shelikof	PP	57.72128	-155.69423
CP1-92	Bear Lake	PP	55.78596	-160.87172	HS1-8.5	Herendeen	PP	55.85998	-160.49368	04RR30B	Shelikof	PP	57.71912	-155.68790
LH1-120	Bear Lake	PP	55.87441	-160.34538	04RR12B	Naknek	PP	57.53561	-156.75188	04RR30D	Shelikof	PP	57.71912	-155.68790
LH1-164	Bear Lake	PP	55.87441	-160.34538	04RR157B	Naknek	PP	55.75607	-160.69526	04DS04B	Kialagvik	PP	57.73551	-155.40000
LH1-182	Bear Lake	PP	55.87441	-160.34538	04RR19B	Naknek	PP	57.41407	-156.50631	04DS09C	Kialagvik	PP	57.30723	-156.43266
LH1-2	Bear Lake	PP	55.87441	-160.34538	04RR20B	Naknek	PP	57.41584	-156.50539	04RR11A	Kialagvik	TOC	57.30629	-156.42686
LH1-66.5	Bear Lake	PP	55.87441	-160.34538	04RR20C	Naknek	IG	57.41584	-156.50539	04RR11B	Kialagvik	TOC	57.30629	-156.42686
LH1-98	Bear Lake	PP	55.87441	-160.34538	04RR22B	Naknek	PP	57.76649	-155.63527	04RR11D	Kialagvik	PP	57.30629	-156.42686
SD1-10	Bear Lake	PP	55.81693	-160.31337	04RR23A	Naknek	PP	57.76330	-155.63304	04RR3B	Kialagvik	PP	57.73318	-156.39858
SD1-41	Bear Lake	PP	55.81693	-160.31337	04RR26B	Naknek	PP	57.74717	-155.68050	04RR9B	Kialagvik	PP	57.39350	-156.37367
SD1-56	Bear Lake	PP	55.81693	-160.31337	04RR2C	Naknek	PP	59.79255	-155.60508	04TJR08	Kialagvik	PP	57.30766	-156.43205
SD1-64	Bear Lake	PP	55.81693	-160.31337	04RR2D	Naknek	PP	59.79255	-155.60508	04TJR08	Kialagvik	TOC	57.30766	-156.43205
SD1-86	Bear Lake	PP	55.81693	-160.31337	04RR6B	Naknek	PP	57.65384	-156.27242	04DS13A	Kamishak	TOC	57.71427	-155.36745
					04RR6D	Naknek	PP	57.65384	-156.27242	04DS14	Kamishak	TOC	57.71432	-155.37116

Table 1. List of samples and analyses performed. [1]Gas Seep; [2]Oil Seep; TOC–total organic carbon; PP–porosity and permeability; WOGC–whole oil geochemistry; HSG–headspace gas analysis.

Analysis	Result	Units/Formula
C1	677881	parts per million by mole
C2	5842	parts per million by mole
C3	173	parts per million by mole
iC4	6	parts per million by mole
C4	3	parts per million by mole
iC5		parts per million by mole
C5	0	parts per million by mole
C6+	7	parts per million by mole
Gas	99.1	C1
Composition	0.9	C2-C4
Percent	0.0	C5-C6+
Wet Gas %	0.9	C2-C4 / C1-C4
Gas Maturity	2.1	i-C4 / n-C4

Table 2. Headspace Gas analysis performed on sample 04RR139A (gas seep in Herendeen Formations; 139 on Figure 3) by Baseline DGSI.

WGC parameters		Thompson[1]			Mango[2]		Halpern[3]
Pristane/Phytane	1.36	A.	BZ/nC_6		P_1		Tr_1
Pristane/nC_{17}		B.	TOL/nC_7		P_2		Tr_2
Phytane/nC_{18}		C.	(nC_6+nC_7)/(CH+MCH)		P_3		Tr_3
nC_{18}/nC_{19}		I.	Isoheptane Value		$5N_1$		Tr_4
nC_{17}/nC_{29}		F.	nC_7/MCH		N_2		Tr_5
CPI Marzi[4]		U.	CH/MCP		$6N_1$	100.00	Tr_7
Normal Paraffins	0.2	R.	nC_7/2MH		K_1		Tr_8
Isoprenoids	2.4	S.	nC_6/22DMB		K_2		C_1
Cycloparaffins	0.0	H.	Heptane Value		$5N_1/6N_1$		C_2
Branched (iso-) Paraffins			MCH/nC_7		P_3/N_2		C_3
BTX aromatics	0.0		mpXYL/nC_8	0.16	ln(24DMP/23DMP)		C_4
Resolved unknowns	96.9						C_5

[1]Thompson, K.F.M., 1983.GCA:V.47, p.303. [2]Mango, F.D., 1994.GCA: V.58, p.895. [3]Halpern, H.I., 1995, AAPG Bull.: V.79, p.801. [4]Marzi, 1993, OrgG; 20, 1301.

Table 3a. Parameters used in whole oil geochemical analysis.

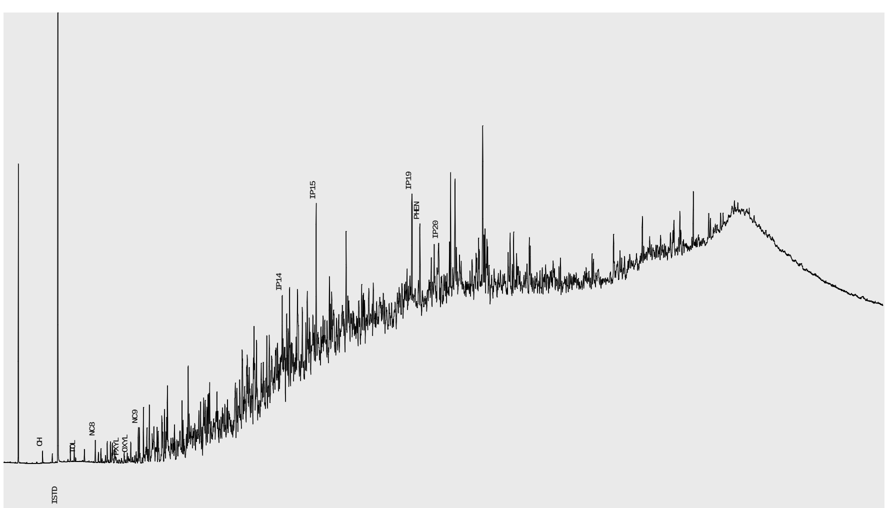

Table 3b. Whole oil geochemical traces.

Peak Label	Compound Name	Ret. Time	Area	Height	ppt (Area)	ppt (Height)
IC4	Iso-alkane C4					
NC4	Normal Alkane C4					
IC5	Iso-alkane C5					
NC5	Normal Alkane C5					
22DMB	2,2-Dimethylbutane					
CP	Cyclopentane					
23DMB	2,3-Dimethylbutane					
2MP	2-Methylpentane					
3MP	3-Methylpentane					
NC6	Normal Alkane C6					
22DMP	2,2-Dimethylpentane					
MCP	Methylcyclopentane					
24DMP	2,4-Dimethylpentane					
223TMB	2,2,3-Trimethylbutane					
BZ	Benzene					
33DMP	3,3-Dimethylpentane					
CH	Cyclohexane	8.242	465	220	0.02	0.02
2MH	2-Methylhexane					
23DMP	2,3-Dimethylpentane					
11DMCP	1,1-Dimethylcyclopentane					
3MH	3-Methylhexane					
1C3DMCP	1-cis-3-Dimethylcyclopentane					
1T3DMCP	1-trans-3-Dimethylcyclopentane					
3EP	3-Ethylpentane					
1T2DMCP	1-trans-2-Dimethylcyclopentane					
NC7	Normal Alkane C7					

Peak Label	Compound Name	Ret. Time	Area	Height	ppt (Area)	ppt (Height)
ISTD	Internal Standard	10.296	87676	39522	3.44	3.44
MCH	Methylcyclohexane					
113TMCP	1,1,3,-Trimethylcyclopentane					
ECP	Ethylcyclopentane					
124TMCP	1,2,4-Trimethylcyclopentane					
123TMCP	1,2,3-Trimethylcyclopentane					
TOL	Toluene	12.705	223	72	0.01	0.01
NC8	Normal Alkane C8	15.345	1066	396	0.04	0.03
IP9	Isoprenoid C9					
MXYL	m-Xylene					
PXYL	p-Xylene	18.563	172	61	0.01	0.01
OXYL	o-Xylene	19.794	390	115	0.02	0.01
NC9	Normal Alkane C9	21.128	1965	634	0.08	0.06
IP10	Isoprenoid C10					
IP11	Isoprenoid C11					
IP13	Isoprenoid C13					
IP14	Isoprenoid C14	40.529	8416	2029	0.33	0.18
IP15	Isoprenoid C15	45.103	12834	3044	0.5	0.27
IP16	Isoprenoid C16					
IP18	Isoprenoid C18					
IP19	Isoprenoid C19 (Pristane)	58	13266	2288	0.52	0.2
PHEN	Phenanthrene	59.081	8044	1691	0.32	0.15
IP20	Isoprenoid C20 (Phytane)	61.616	9720	1162	0.38	0.1
C25HBI	Highly Branch Isoprenoid C25					
NC22 to NC41	Normal Alkane C10 to Normal Alkane C41	No	Results			

Table 3c. Whole oil geochemical analysis results.

Parameter	Formula
WGC Parameters	
Pristane/Phytane	IP19/IP20
Pristane/nC17	IP19/NC17
Phytane/nC18	IP20/NC18
nC18/nC19	NC18/NC19
nC17/nC29	NC17/NC29
CPI Marzi[4]	((NC23+NC25+NC27)+(NC25+NC27+NC29))/(2*(NC24+NC26+NC28))
Normal Paraffins	100*(NC4+NC5+NC6+NC7+NC8+NC9+NC10+NC11+NC12+NC13+NC14+NC15+NC16+NC17+NC18+NC19+NC20+NC21+NC22+NC23+NC24+NC25+NC26+NC27+NC28+NC29+NC30+NC31+NC32+NC33+NC34+NC35+NC36+NC37+NC38+NC39+NC40+NC41)/TOTAL_RESOLVED.F(0.0)
Isoprenoids	100*(IP9+IP10+IP11+IP13+IP14+IP15+IP16+IP18+IP19+IP20+CH25HBI)/TOTAL_RESOLVED
Cycloparaffins	100*(CP+MCP+CH+11DMCP+1T3DMCP+1T2DMCP+MCH+113TMCP+ECP+124TMCP+123TMCP+1C3DMCP+1C2DMCP)/TOTAL_RESOLVED
Branched (iso-) Paraffins	100*(IC4+IC5+22DMB+23DMB+2MP+3MP+22DMP+24DMP+223TMB+33DMP+2MH+23DMP+3MH+3EP)/TOTAL_RESOLVED
BTX aromatics	100*(BZ+TOL+XYL)/TOTAL_RESOLVED
Thompson[1]	
BZ/nC6	BZ/NC6
TOL/nC7	TOL/NC7
(nC6+nC7)/(CH+MCH)	(NC6+NC7)/(CH+MCH)
Isoheptane Value	(2MH+3MH)/(1C3DMCP+1T3DMCP+1T2DMCP)
nC7/MCH	NC7/MCH
CH/MCP	CH/MCP
nC7/2MH	NC7/2MH
nC6/22DMB	NC6/22DMB
Heptane Value	NC7*100/(CH+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+1T2DMCP+MCH+NC7)
MCH/nC7	MCH/NC7
mpXYL/nC8	XYL/NC8
Mango[2]	
P1	(100*NC7)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
P2	100*(2MH+3MH)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
P3	100*(3EP+33DMP+23DMP+24DMP+22DMP+223TMB)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
5N1	100*(ECP+1T2DMCP)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
N2	100*(11DMCP+1C3DMCP+1T3DMCP)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
6N1	100*(MCH+TOL)/(22DMP+24DMP+223TMB+33DMP+2MH+23DMP+11DMCP+3MH+1C3DMCP+1T3DMCP+3EP+1T2DMCP+NC7+MCH+ECP+TOL)
K1	(2MH+23DMP)/(3MH+24DMP)
K2	(2MH+3MH)/(2MH+3MH+11DMCP+1C3DMCP+1T3DMCP)
5N1/6N1	(ECP+1T2DMCP)/(MCH+TOL)
P3/N2	(3EP+33DMP+23DMP+24DMP+22DMP+223TMB)/(11DMCP+1C3DMCP+1T3DMCP)
ln(24DMP/23DMP)	ln(24DMP/23DMP)
Halpern[3]	
Tr1	TOL/11DMCP
Tr2	NC7/11DMCP
Tr3	3MH/11DMCP
Tr4	2MH/11DMCP
Tr5	(2MH+3MH)/11DMCP
Tr7	1T3DMCP/11DMCP
Tr8	(2MH+3MH)/(22DMP+23DMP+24DMP+33DMP+3EP)
C1	22DMP/(22DMP+23DMP+24DMP+33DMP+3EP)
C2	23DMP/(22DMP+23DMP+24DMP+33DMP+3EP)
C3	24DMP/(22DMP+23DMP+24DMP+33DMP+3EP)
C4	33DMP/(22DMP+23DMP+24DMP+33DMP+3EP)
C5	3EP/(22DMP+23DMP+24DMP+33DMP+3EP)

Table 3d. Whole oil geochemical formulas.

Sample	Formation	Sample Type	TOC Wt. %	S1 mg/g	S2 mg/g	S3 mg/g	Tmax	HI	OI	S1/ TOC	PI	Verified
04RR140B	Bear Lake	Outcrop	0.21	0.02	0.07	0.34	464	33	162	9	0.22	
04RR140E	Bear Lake	Outcrop	0.08	0.09	0.07	0.44	520	88	550	111	0.56	
04RR138D	Stepovak	Outcrop	9.54	0.04	0.41	0.41	548	4	4	0	0.09	TOC
04RR142A	Chignik	Outcrop	0.02	0.02	0.10	0.26	526	500	1300	98	0.16	
04RR156C	Herendeen	Outcrop	0.19	0.01	0.21	0.63	545	111	332	5	0.04	
04-TJR-4G	Naknek*	Outcrop	2.19	0.03	8.49	0.51	420	389	23	1	0.00	TOC RE
04-DS-10A	Shelikof	Outcrop	0.20	0.00	0.10	0.26	497	50	130	0	0.00	
04-DS-10B	Shelikof	Outcrop	0.18	0.01	0.10	0.13	544	56	72	5	0.09	
04-DS-11	Shelikof	Outcrop	0.36	0.01	0.25	0.19	428	69	53	3	0.04	
04-RR-13C	Shelikof	Outcrop	0.23	0.02	0.17	0.15	545	74	65	9	0.10	
04-RR-11A	Kialagvik	Outcrop	0.81	0.30	0.58	0.32	444	72	40	37	0.34	
04-RR-11B	Kialagvik	Outcrop	0.57	0.09	0.33	0.28	465	58	49	16	0.21	
04-TJR-08	Kialagvik	Outcrop	0.54	0.08	0.33	0.13	461	61	24	15	0.19	
04-DS-13A	Kamishak	Outcrop	2.38	1.28	14.24	0.50	429	598	21	54	0.08	TOC RE
04-DS-14	Kamishak	Outcrop	1.12	0.33	5.31	0.25	425	474	22	30	0.06	TOC RE

*Snug Harbor Member

Table 4. Total organic carbon, pyrolysis analysis of 15 outcrop samples performed by Baseline DGSI.

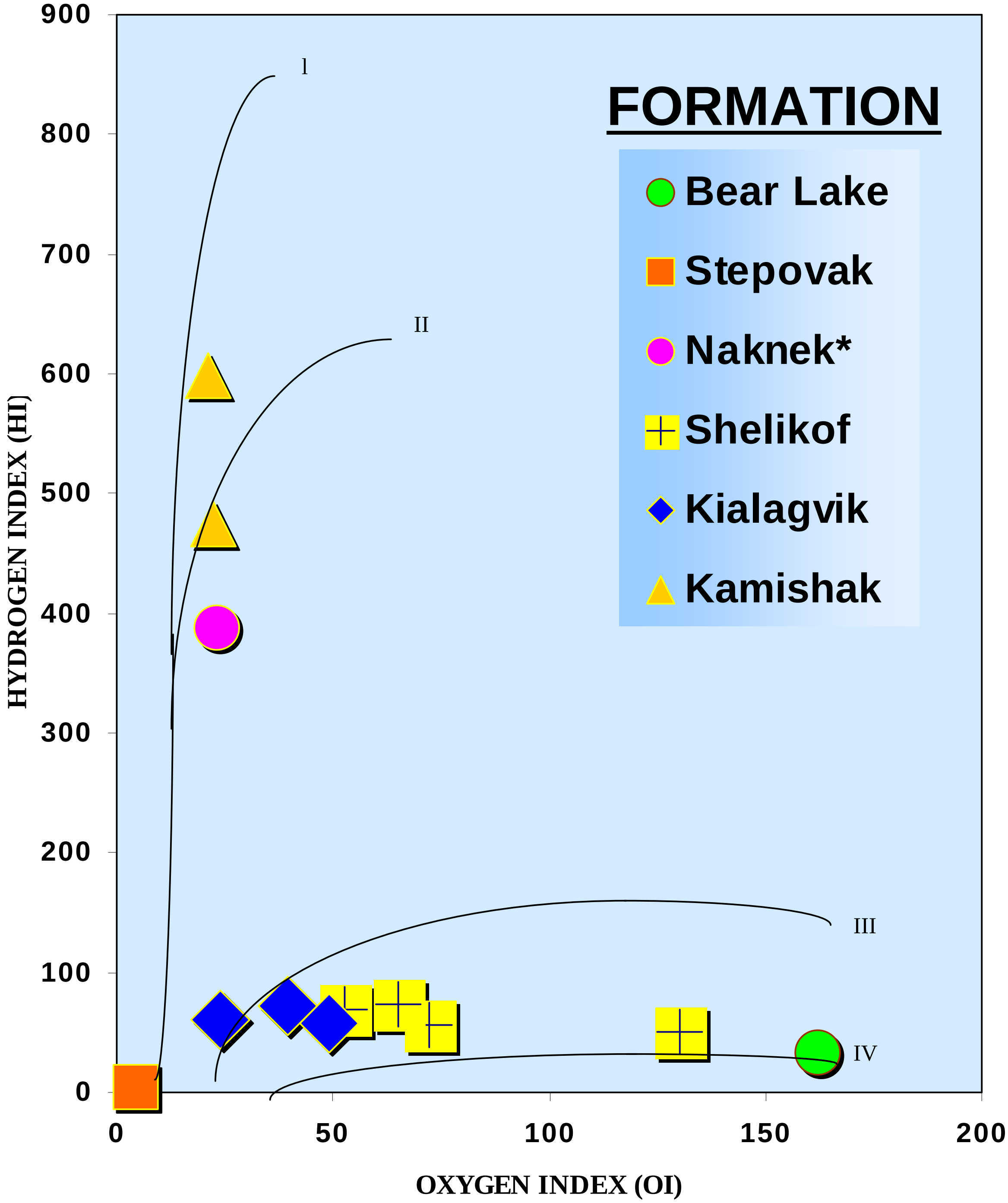

*Figure 6. Kerogen type determination of total organic carbon outcrop samples. Types I and II will generate oil, type III gas, and type IV little or no hydrocarbons. *Snug Harbor Member.*

Sample ID	Porosity %	Formation	Permeability (millidarcies) Klinkenberg	Kair	Probe	Grain Density g/cm^3
04RR140C	11.7	Bear Lake	0.613	0.898		2.53
SD1-56	8.3	Bear Lake	0.003	0.010		2.71
LH1-164	4.4	Bear Lake	0.005	0.013		2.73
CP1-138	7.5	Bear Lake	0.006	0.017		2.71
SD1-64	10.6	Bear Lake	0.024	0.048		2.69
CP1-38	6.2	Bear Lake	0.027	0.053		2.66
LH1-120	8.3	Bear Lake	0.032	0.061		2.67
CP1-92	9.6	Bear Lake	0.041	0.076		2.69
LH1-66.5	6.5	Bear Lake	0.055	0.098		2.67
04RR148B	9.8	Bear Lake	0.063	0.110		2.68
SD1-86	4.9	Bear Lake	0.184	0.280		2.68
CP1-11	13.6	Bear Lake	0.190	0.288		2.66
SD1-10	10.8	Bear Lake	0.191	0.310		2.66
04RR152C	11.9	Bear Lake	0.242	0.377		2.72
LH1-2	8.9	Bear Lake	0.474	0.691		2.68
CP1-26	11.2	Bear Lake	0.582	0.870		2.64
04RR8B	36.1	Bear Lake	ns	ns	41.4	2.63
04RR8D	39.6	Bear Lake	ns	ns	0.251	2.49
04RR8E	38.4	Bear Lake	ns	ns	0.066	2.46
04RR153D	9.2	Bear Lake	ns	ns	0.180	2.71
LH1-98	16.9	Bear Lake	ns	ns	0.065	2.69
LH1-182	11.3	Bear Lake	ns	ns	0.037	2.62
SD1-41	10.0	Bear Lake	ns	ns	0.08	2.68
04RR163C	14.1	Bear Lake	ns	ns	0.448	2.73
CP1-178	11.2	Bear Lake	ns	ns	0.870	2.66
04RR150B	2.6	Chignik	0.001	0.004		2.71
04RR141B	13.8	Chignik	0.008	0.020		2.69
04RR149B	4.6	Chignik	0.308	0.447		2.71
04RR151C	7.1	Chignik	1.230	1.694		2.66
04RR142B	12.4	Chignik	ns	ns	1.950	2.68
04RR156B	4.6	Herendeen	0.001	0.004		2.70
04RR156D	1.1	Herendeen	0.002	0.006		2.68
HS1-16	7.3	Herendeen	0.002	0.007		2.67
HS1-8.5	5.1	Herendeen	0.007	0.018		2.60
HS1-2.5	7.9	Herendeen	0.007	0.018		2.70
HS1-12	5.3	Herendeen	0.009	0.022		2.68
HS1-5.5	6.3	Herendeen	0.049	0.088		2.73
041RR139D	11.0	Herendeen	0.793	1.188		2.68
04RR139C	11.6	Herendeen	ns	ns	1.080	2.64
04RR9B	9.7	Kialagvik	0.001	0.005		2.77

Sample ID	Porosity %	Formation	Permeability (millidarcies) Klinkenberg	Kair	Probe	Grain Density G/cm^3
04RR11D	3.9	Kialagvik	0.060	0.106		2.63
04TJR08	7.4	Kialagvik	0.444	0.698		2.76
04DS04B	4.9	Kialagvik	ns	ns	0.021	2.70
04DS09C	4.8	Kialagvik	ns	ns	0.053	2.74
04RR3B	13.4	Kialagvik	ns	ns	0.027	2.70
SR2-6	35.4	Milky River	62.237	73.113		2.75
SR1-3.5	32.7	Milky River	222.139	245.875		2.68
SR2-89.5	35.3	Milky River	3425.436	3553.977		2.70
04RR154B	42.0	Milky River	ns	ns		2.81
04RR158C	35.0	Milky River	ns	ns	125.000	2.73
04RR158G	35.6	Milky River	ns	ns	76.600	2.63
04RR6B	2.7	Naknek	0.002	0.008		2.51
04RR23A	1.5	Naknek	0.005	0.014		2.68
04TJR09	5.3	Naknek	0.026	0.051		2.52
04RR2C	3.8	Naknek	0.074	0.126		2.63
04RR12B	5.0	Naknek	0.114	0.184		2.61
04RR2D	4.6	Naknek	0.137	0.216		2.60
04RR7D	4.5	Naknek	1.562	2.195		2.56
04RR19B	6.3	Naknek	2.433	3.382		2.62
04RR26B	4.6	Naknek	3.829	5.366		2.61
04RR20B	13.9	Naknek	ns	ns	0.223	2.74
04RR22B	6.5	Naknek	ns	ns	48.1	2.56
04RR6D	7.2	Naknek	ns	ns	20.0	2.71
04RR7B	7.2	Naknek	ns	ns	37.7	2.57
04RR157B	8.1	Naknek	44.113	52.914		2.59
04RR30B	3.5	Shelikof	0.002	0.006		2.70
04RR18B	3.6	Shelikof	0.004	0.010		2.62
04RR1D	6.7	Shelikof	0.005	0.014		2.63
04RR16B	3.7	Shelikof	0.006	0.016		2.73
04RR15G	5.3	Shelikof	0.008	0.019		2.73
04RR29A	5.2	Shelikof	0.008	0.020		2.65
04RR28B	7.7	Shelikof	0.043	0.079		2.80
04RR15B	8.5	Shelikof	0.110	0.178		2.73
04RR15D	6.4	Shelikof	0.165	0.254		2.71
04RR13B	4.9	Shelikof	0.374	0.522		2.69
04RR18D	8.4	Shelikof	0.446	0.689		2.73
04RR30D	10.1	Shelikof	ns	ns	0.462	2.70
04RR138	16.6	Stepovak	0.004	0.012		2.70
04RR155B	7.0	Tolstoi	0.002	0.005		2.71
04RR168B	4.4	Tolstoi	0.004	0.010		2.75
04RR155B	9.6	Tolstoi	0.099	0.163		2.72

Table 5. Porosity and permeability (conventional core analysis) of outcrop samples performed by Core Laboratories, Inc. Performed at 400 psig net confining stress. ns=not suitable for analysis.

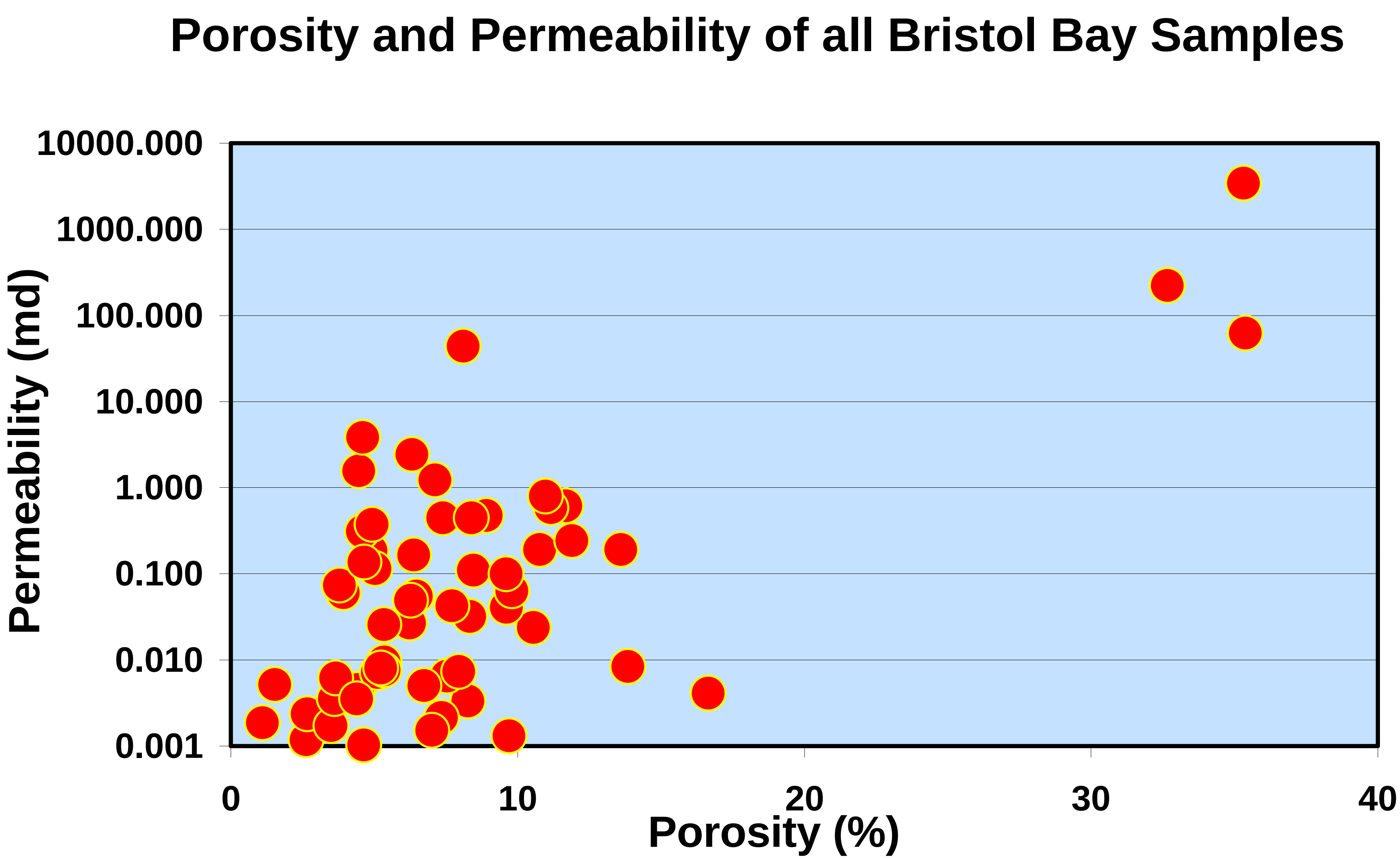

Figure 7. Porosity and permeability of outcrop samples (undifferentiated); md - millidarcies.

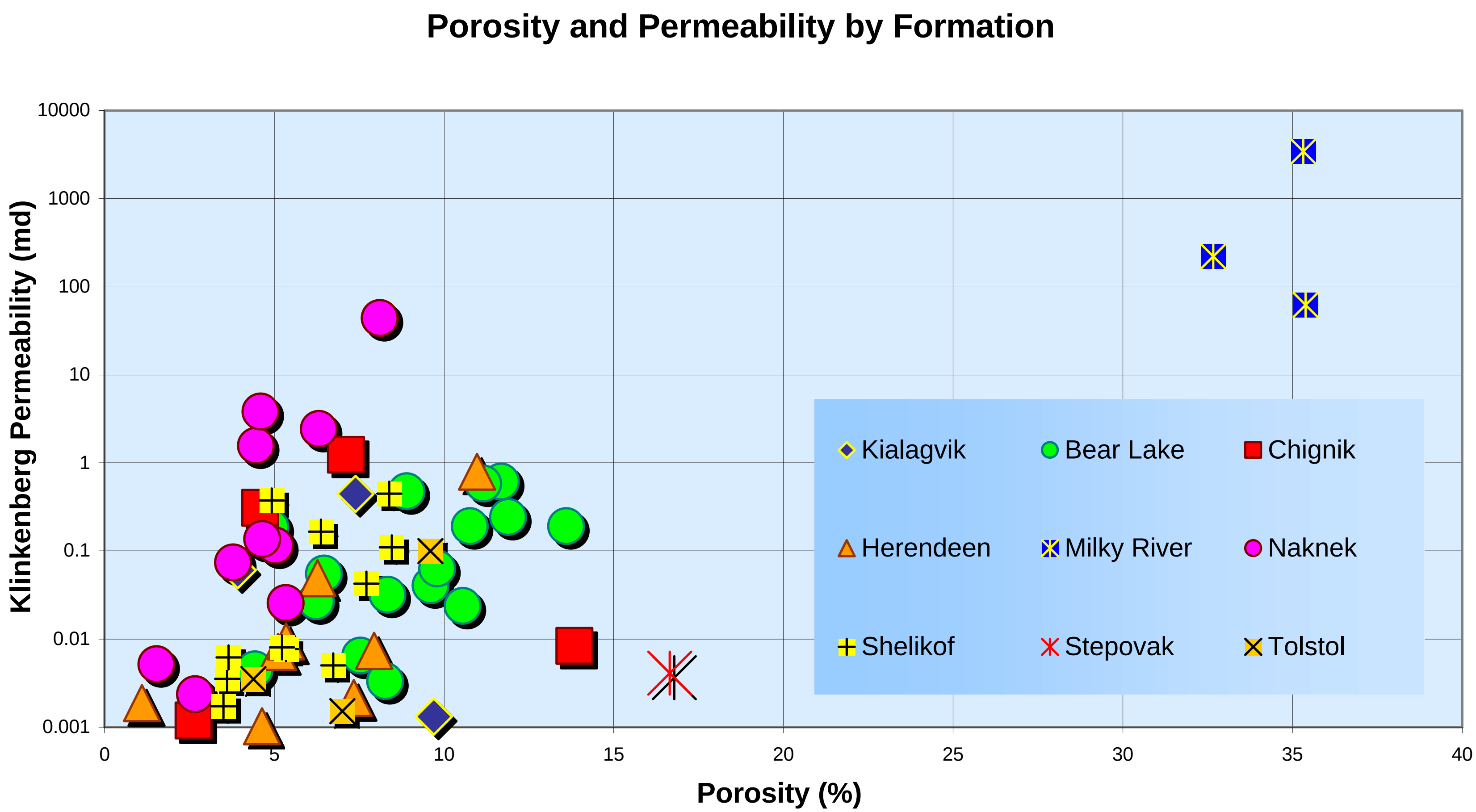

Figure 8. Porosity and permeability of outcrop samples (by formation); md - millidarcies.

Test	Result	Units
SiO2	52.11	%
Al2O3	14.47	%
Fe2O3	11.89	%
CaO	5.42	%
MgO	4.13	%
Na2O	1.61	%
K2O	0.84	%
Cr2O3	0.01	%
TiO2	1.21	%
MnO	0.23	%
P2O5	0.26	%
SrO	0.04	%
BaO	0.06	%
LOI	7.44	%
total	99.72	%
FeO	4.7	%
weight sample	327.4	grams
weight heavy@2.96	23.007	grams
weight light@2.96	303.3	grams
weight total@2.96	326.3	grams
heavy magnetic fraction	18.945	grams
heavy non-magnetic fraction	4.062	grams
light magnetic fraction	56.334	grams
light non-magnetic fraction	246.99	grams

Table 6. Inorganic geochemical analysis performed by ACME Analytical Lab, on outcrop sample 04RR20C, from the Snug Harbor Member of the Naknek Formation.

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