EVALUATION OF POTENTIAL PETROLEUM SYSTEMS IN THE NECHAKO BASIN

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ABSTRACT

Three rock suites were assembled to evaluate components of potential petroleum systems in the Nechako region. Skeena Group sandstones collected from the north-westernmost part of the Nechako region in 2007 showed low permeability, indicating generally poor reservoir quality. Surface samples collected in 2007 and 2008 along the southeastern edge of the Nechako region of mainly Jackass Mountain Group rocks returned TOC values over 1% from 5 of 8 samples. Vitrinite reflectance data indicate that rocks in the southern part of the basin region are mainly in the oil and gas window. Three of 11 samples of sandstones from the Yalakom River area have moderate permeability and porosity values that could be sufficient for a gas reservoir. Subsurface samples collected from archived drill cuttings from oil and gas exploration wells were analysed to constrain age, stratigraphic, and structural issues raised by previous work. Results identify complexities in the structural relationships between prospective units in the Nazko River area.

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Key Words*:* Nechako Basin, oil and gas, petroleum, hydrocarbons, Rock-Eval, source beds, vitrinite reflectance, thermal maturity, reservoir, porosity, permeability, palynology, Skeena Group, Jackass Mountain Group, Taylor Creek Group, Nemaia Formation, Nazko River

INTRODUCTION

Three rock suites were assembled to evaluate components of potential petroleum systems in the Nechako region (Figure 1).

1. Eight outcrop samples of Skeena Group sandstones collected from the northwesternmost part of the Nechako region in 2007 were analysed for porosity, permeability, and density to assess their potential reservoir quality.
2. Fifty-five outcrop samples of sandstones, mainly of the Jackass Mountain Group, collected in 2007 and 2008 along the southeastern edge of the Nechako region were analysed for reservoir quality, source rock potential, and thermal history.
3. Thirty subsurface samples were collected from archived drill cuttings from oil and gas exploration wells drilled in 1960 and 1981 in the Nazko River valley and were analysed to constrain age, stratigraphic, and structural issues raised by previous work on cuttings (Riddell et al. 2007).

Results of reservoir quality (porosity and permeability), Rock-Eval organic chemistry, and vitrinite reflectance analyses are presented here, along with comments on some preliminary results of new palynological analyses. These results build on work done in previous years (Ferri and Riddell 2006; Riddell et al. 2007; Riddell and Ferri 2008; Brown et al. 2008) on various stratigraphic elements (Figure 2) of the Nechako region. Apatite fission track (AFT) dating, zircon U-Pb radiometric, and palynological analyses are ongoing. Those results will appear in future publications.

Northwest Nechako suite

The reservoir quality of Skeena Group rocks in the north-western corner of the Nechako region was assessed through porosity, permeability, and density measurements (Table 1) conducted by Core Laboratories of Calgary on eight samples of sandstone from south of Houston, British Columbia (Figure 1). In this region, Skeena Group outcrops are dominated by resistant, homogenous, well-sorted, greenish-grey and blocky weathering sandstones. The sandstones are generally massive or have barely discernible bedding marked by wispy black carbonaceous material. The most abundant clast type is green chert; also present are black chert, black lithic fragments, feldspar crystals, and rare pink chert. Muscovite flakes are almost ubiquitous (Riddell and Ferri 2008).

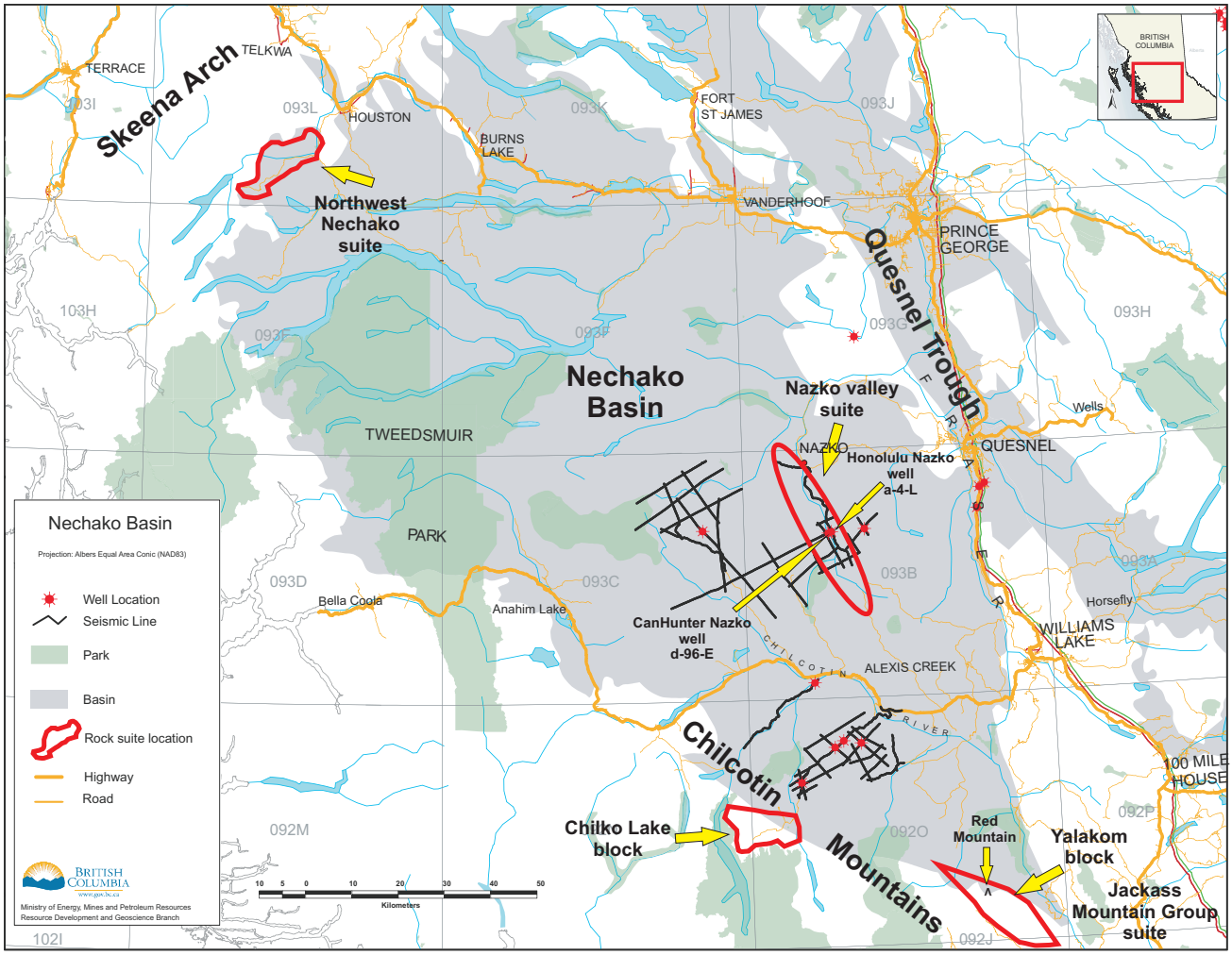


Figure 1. Location map.

RESULTS

Porosity values are mainly poor, but three samples have moderate to good porosity (5.4% to 9.9%). However, permeability values (less than 0.1 mD) for all eight samples are low.

Jackass Mountain Group suite

Regional facies patterns and basin architecture of Cretaceous Jackass Mountain Group sedimentary rocks were studied over three field seasons (2006 to 2008) by Mahoney et al. (2009). Their study focussed on the southeastern fringe of the Nechako Basin, where the Jackass Mountain Group is well exposed in two areas referred to by Mahoney et al. (2009) as the Chilko Lake and Yalakom blocks (Figure 1). The researchers collected 49 samples for analysis of reservoir quality, source bed potential, and thermal history. Most samples were from the Jackass Mountain Group, but a few samples of the Jurassic Nemaia Formation and the Cretaceous Taylor Creek Group were included.

RESULTS

Thirty hand-drilled plugs of sandstones from the Yalakom and Chilko Lake blocks (Mahoney et al. 2009) show that most samples (Table 2) have permeabilites of less than 0.01 mD; the two best samples have permeabilities of 0.12 and 0.27 mD and were collected from the Nine Mile Ridge and Madsen Creek sections in the Yalakom block. Three of the samples had moderate porosity values ranging from 5.0% to 5.7%. Brown et al. (2008) noted that pre-Late Cretaceous sedimentary rocks in the Nechako region have suffered considerable syn-depositional to very early compaction, causing destruction of primary porosity. As a result, primary depositional features such as grain size and sorting are not reliable predictors of reservoir quality. Post-depositional events such as the development of fracture permeability and of secondary porosity resulting from dissolution of minerals control the distribution of localized areas of good reservoir quality.

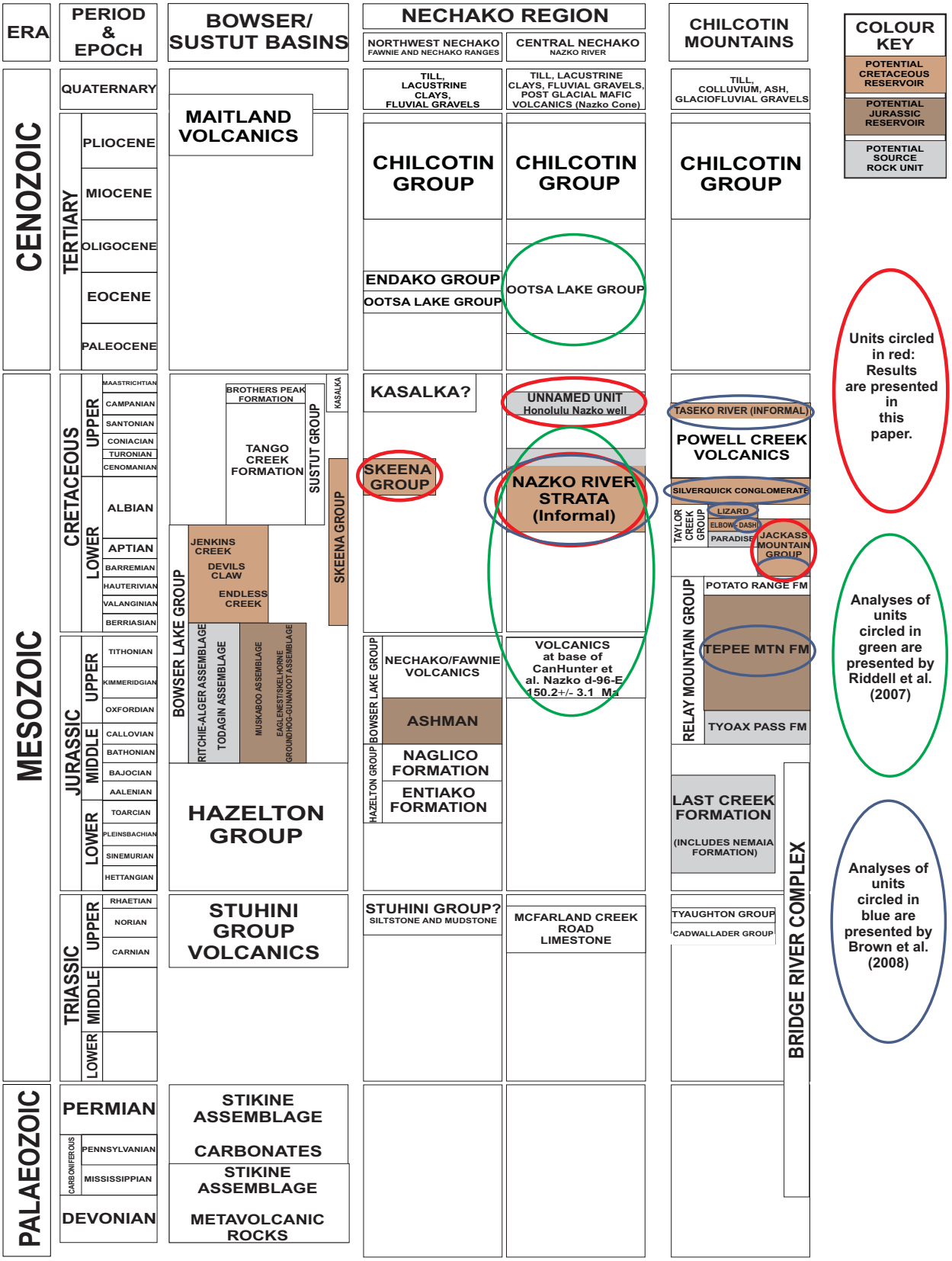


Figure 2. Nechako Basin stratigraphic correlation chart, and stratigraphic locations of samples.

TABLE 1. POROSITY AND PERMEABILITY DATA FOR SKEENA GROUP SANDSTONES FROM THE NORTHWESTERN NECHAKO REGION.

Sample	Permeability (Maximum) Kair mD	Porosity (Helium) %	Bulk density (kg/m3)	Grain Density (kg/m3)	Location Easting UTM NAD 83	Location Northing UTM NAD 83	Sandstone grain size
JR07-44	0.06	5.4	2550	2700	613738	5986834	medium
JR07-47	0.02	3.3	2600	2690	614667	5990358	medium
JR07-50	0.04	3.7	2560	2660	614576	5993426	medium
JR07-53	0.03	8.0	2510	2730	621450	5998507	medium
JR07-54	<.01	2.6	2630	2700	612559	5993131	medium
JR07-58	0.01	3.3	2610	2700	613013	5993990	fine
JR07-62	0.01	2.1	2640	2700	619260	5998870	medium
JR07-64	0.01	9.9	2420	2690	621975	5998688	medium

Mahoney et al. collected 11 samples for Rock-Eval analysis to determine source bed potential. They included shaly intervals from each of the following:

- the Beece Creek succession of the Taylor Creek Group (Schiarizza et al. 2002) from near Mount Tatlow (measured section uTCG of Mahoney et al. 2009),
- the Jackass Mountain Group on Mount Nemaia (measured section C in the Chilko Lake block of Mahoney et al. 2009),
- the Jackass Mountain Group in the Camelsfoot Range (including measured sections B and D of Mustard et al. [2008] in the Yalakom block).

Rock–Eval analyses (Table 3) provide information about the amount, quality, type, and maturity of organic carbon in the samples. A few of the samples from the Yalakom block have good to very good total organic carbon (TOC) values. Values ranging from about 2% to 11% were returned from shales within volcanic lithic sandstones of the Churn Creek facies (Schiarizza and Gaba 1997) of the Jackass Mountain Group near Red Mountain in the Yalakom block (Figure 1) and from crumbly brown shale and sand from the Madson Creek and Nine Mile Ridge sections (measured sections B and D of Mustard et al. [2008]). Rock-Eval data ratios on the two plots in Figure 3 indicate that kerogen from all sampled units is Type III (gas-prone) (Peters 1986; Langford and Blanc-Valleron 1990), which indicates that the carbon source was terrestrial plant material.

Fourteen samples were submitted for vitrinite reflectance analysis; thirteen were collected from the Yalakom block, (including 5 Red Mountain samples) and one from the Chilko Lake block. Reflectance values (Table 4) indicate maturities ranging through the oil and gas windows (Figure 4). Samples from the Red Mountain area are less mature; they are all in the oil window. The samples are plotted under the organic material Type III part of the diagram, reflecting that the Rock-Eval results from the area indicate that Type III kerogens are present.

Nazko Valley suite—archived drill cuttings

Results of previous work on archived core and cuttings from Nechako oil and gas exploration wells (Riddell et al. 2007) raised questions about the stratigraphy in the two Nazko River valley wells—Honolulu Nazko a-4-L (1960) and Canadian Hunter et al. (CanHunter) Nazko d-96-E (1981) (Figures 1 and 5). Previous sampling included only core, but not cuttings, from the Honolulu Nazko well, so in this study cuttings were submitted for palynology, thermal history (apatite fission track and vitrinite reflectance), and geochronology analyses in order to address the following issues:

- A single core sample from green shale in Honolulu Nazko a-4-L at 7364 ft (2245 m) depth (see Figure 5) produced Campanian palynomorphs (Riddell et al. 2007), indicating that a probable thrust fault is placing older (Albian-Cenomanian) over younger. A fault was proposed by the Honolulu Oil Corporation (Taylor 1961), also based on palynological analyses that indicated that "Cretaceous to Middle Upper Cretaceous" rocks occur below Lower Cretaceous strata in the well. Cuttings were submitted to find support for the Campanian date and to constrain the stratigraphic extent of the Campanian unit.
- A greenish shale unit occurs between about 2500 and 3000 m in the CanHunter Nazko (d-96-E) well (Figure 5). No age data were available for the shale, so in 2008 cuttings were submitted for palynological analyses to test whether it correlates with the Campanian green shale in the Honolulu Nazko well.
- Rock-Eval analyses by Osadetz et al. (2003) identified a 510 ft (155 m) thick interval of carbonaceous shale with good TOC and S2 values in Honolulu Nazko a-4-L between depths of 220 and 730 ft (67 and 222 m). Cuttings were submitted for palynological and vitrinite reflectance analyses to provide a better understanding of this potential source rock.

TABLE 2. POROSITY AND PERMEABILITY DATA FOR SANDSTONES (MAINLY JACKASS MOUNTAIN GROUP) FROM THE CHILCOTIN MOUNTAINS ON THE SOUTHERN FRINGE OF THE NECHAKO REGION.

Sample	Permeability (Maximum) Kair mD	Porosity (Helium) fraction	Bulk density (kg/m3)	Grain Density (kg/m3)	Area	Location Easting UTM NAD 83	Location Northing UTM NAD 83	Formation or Group	Sandstone grain size
07KM048A	<0.01	0.001	2790	2790	Chilko	421337	5713814	JMG- A	fine
07KM053C	<0.01	0.021	2710	2770	Chilko	421950	5713195	JMG- B	medium
07KM057A	<0.01	0.004	2770	2780	Chilko	422600	5712436	JMG- C	medium
07KM058B	<0.01	0.003	2830	2840	Chilko	422819	5712126	JMG- C	fine
07KM060B	<0.01	0.014	2730	2770	Chilko	419953	5713075	JMG- A	medium
07KM063A	<0.01	0.001	2820	2820	Chilko	419758	5712482	JMG- A	fine
07KM07	<0.01	0.001	2830	2830	Chilko	425453	5705048	JMG- B	fine
07KM077	<0.01	0.001	2810	2810	Chilko	424989	5705943	JMG- C	medium
07KM087	<0.01	0.008	2790	2810	Chilko	424574	5704310	Nemaia	fine
07JRG026P	<0.01	0.052	2580	2720	Yalakom	549388	5661406	JMG - F	medium
07JRG026H2	0.09	0.036	2630	2730	Yalakom	549436	5661406	JMG - F	coarse
07JRG026A2	<0.01	0.022	2640	2700	Yalakom	549566	5661291	JMG - F	medium
07JRG035B	<0.01	0.002	2830	2840	Yalakom	542640	5652417	JMG - D	fine
07JRG040A	<0.01	0.001	2770	2770	Yalakom	538625	5655828	JMG - D	fine
07JRG053B	0.12	0.057	2550	2710	Yalakom	533829	5659458	JMG - F	medium
07JRG055A	<0.01	0.031	2620	2710	Yalakom	561244	5654944	JMG - E	coarse
15MMF07	<0.01	0.024	2650	2710	Chilko	436878	5694862	Taylor Creek	fine
28MMF07	<0.01	0.022	2610	2670	Chilko	436844	5694331	Taylor Creek	medium
36MMF07	<0.01	0.02	2640	2690	Chilko	436803	5693885	Taylor Creek	medium
42MMF07	0.02	0.013	2700	2740	Chilko	436783	5693842	Taylor Creek	fine
49MMF07	<0.01	0.014	2710	2750	Chilko	436751	5693702	Taylor Creek	medium
35JBM07	<0.01	0.048	2590	2720	Yalakom	550562	5660591	JMG-E	medium
36JBM07	<0.01	0.042	2610	2720	Yalakom	549715	5661066	JMG-E	medium
37JBM07	0.06	0.045	2610	2730	Yalakom	545803	5661460	JMG-E	coarse
JBM07-47	0.27	0.05	2550	2680	Yalakom	563266	5656142	JMG-E	medium
50JBM07	<0.01	0.019	2690	2740	Chilcotin Mts.	490326	5665238	Taylor Creek	fine
58JBM07	<0.01	0.037	2650	2750	Chilko	510016	5667239	Taylor Creek	medium
07KM048A	<0.01	0.001	2790	2790	Chilko	436844	5694331	Taylor Creek	fine
07KM053C	<0.01	0.021	2710	2770	Chilko	436803	5693885	Taylor Creek	medium
07KM057A	<0.01	0.004	2770	2780	Chilko	436783	5693842	Taylor Creek	medium
07KM058B	<0.01	0.003	2830	2840	Chilko	436751	5693702	Taylor Creek	fine

- Previous Rock-Eval analyses by Osadetz et al. (2002) identified some promising TOC values from intervals where they were unexpected, specifically shaly intervals in a mainly volcanic unit near the base of the Honolulu Nazko well. These cuttings were re-examined and Rock-Eval analyses were rerun to confirm the 2002 results.
- Nineteen samples were collected from the Honolulu Nazko well cuttings for vitrinite reflectance analyses to establish a thermal maturity profile for the well.
- The age of the diorite at the base of the Honolulu Nazko well was determined to be "Cretaceous or older" by K-Ar dating done for the Honolulu Oil Company (Taylor 1961). A new sample was submitted for U-Pb zircon dating to get a more precise and reliable age.

TABLE 3. ROCK-EVAL DATA FOR ANALYSES CONDUCTED FOR THE NECHAKO PROJECT IN 2008.

Field ID	Formation	Area	Easting	Northing	TOC	S1	S2	PI	S3	Tmax	Tpeak	S3CO	PC(%)	RC%	HI	OICO	OI	MINC%
39JBM07	Taylor Creek Grp.	Mt. Tatlow	436882	5694680	0.39	0.01	0.04	0.16	0.31	607	646	0.14	0.02	0.37	10	36	79	0.1
40JBM07	Taylor Creek Grp.	Mt. Tatlow	436858	5694464	0.48	0.01	0.03	0.18	0.60	523	562	0.06	0.02	0.46	6	12	125	0.1
HFB-08-07	Jackass Mtn. Grp.	Mt. Nemaia	426045	5704835	0.16	0.01	0.03	0.17	0.28	494	533	0.04	0.01	0.15	19	25	175	0.0
HFB-08-09	Jackass Mtn. Grp.	Mt. Nemaia	425654	5704815	0.28	0.01	0.05	0.14	0.32	481	520	0.00	0.02	0.26	18	0	114	0.1
HFB-08-46	Jackass Mtn. Grp.	Nine Mile Ridge	547258	5669762	2.51	0.07	0.86	0.08	2.34	484	523	0.70	0.18	2.33	34	28	93	0.2
HFB-08-53	Jackass Mtn. Grp.	Nine Mile Ridge	555290	5672429	0.27	0.00	0.02	0.21	0.74	367	406	0.04	0.03	0.24	7	15	274	0.1
HFB-08-55	Jackass Mtn. Grp.	Madsen Creek	561982	5657241	2.02	0.01	0.14	0.08	3.93	533	572	0.32	0.14	1.88	7	16	195	0.3
HFB-08-56	Jackass Mtn. Grp.	Madsen Creek	561723	5657447	2.43	0.01	0.08	0.15	4.21	528	567	0.07	0.13	2.30	3	3	173	0.4
40EAB08	Jackass Mtn. Grp.	Red Mountain	527305	5672151	1.92	0.02	0.49	0.03	2.33	461	500	0.46	0.14	1.78	26	24	121	0.2
41EAB08	Jackass Mtn. Grp.	Red Mountain	527331	5673288	5.18	0.04	5.07	0.01	4.04	442	481	1.12	0.61	4.57	98	22	78	0.3
58EAB08	Jackass Mtn. Grp.	Red Mountain	527051	5675543	10.82	0.03	1.36	0.02	12.05	532	571	1.82	0.62	10.20	13	17	111	7.1

Depth (feet)	Section	Well	Easting	Northing	TOC	S1	S2	PI	S3	Tmax	Tpeak	S3CO	PC(%)	RC%	HI	OICO	OI	MINC%
6975	Campanian	a-4-L	471599	5835406	0.49	0.14	0.41	0.25	0.21	444	483	0.05	0.06	0.43	84	10	43	0.6
6980	Campanian	a-4-L	471599	5835406	0.45	0.08	0.30	0.21	0.23	446	485	0.04	0.04	0.41	67	9	51	0.3
8685	Nechako Volcanics?	a-4-L	471599	5835406	0.06	0.01	0.03	0.30	0.46	414	453	0.03	0.02	0.04	50	50	767	0.2
8700	Nechako Volcanics?	a-4-L	471599	5835406	3.55	13.77	26.98	0.34	0.28	391	430	0.06	3.40	0.15	760	2	8	0.1
8705	Nechako Volcanics?	a-4-L	471599	5835406	3.92	15.42	29.72	0.34	0.27	385	424	0.17	3.77	0.15	758	4	7	0.1
8710	Nechako Volcanics?	a-4-L	471599	5835406	6.27	22.83	50.06	0.31	0.29	400	439	0.08	6.07	0.20	798	1	5	0.2
8715	Nechako Volcanics?	a-4-L	471599	5835406	7.69	25.79	64.05	0.29	0.31	412	451	0.13	7.48	0.21	833	2	4	0.1
8720	Nechako Volcanics?	a-4-L	471599	5835406	5.74	20.22	46.65	0.30	0.25	405	444	0.04	5.56	0.18	813	1	4	0.2
9575	Nechako Volcanics?	a-4-L	471599	5835406	0.59	3.60	2.08	0.63	0.33	299	338	0.06	0.49	0.10	353	10	56	1.1
9580	Nechako Volcanics?	a-4-L	471599	5835406	3.32	13.75	24.63	0.36	0.42	312	351	0.02	3.20	0.12	742	1	13	0.4
9585	Nechako Volcanics?	a-4-L	471599	5835406	0.06	0.09	0.12	0.43	0.26	327	366	0.07	0.03	0.03	200	117	433	0.4
9915	Nechako Volcanics?	a-4-L	471599	5835406	0.27	0.11	0.22	0.35	0.45	312	351	0.04	0.05	0.22	81	15	167	0.4
9920	Nechako Volcanics?	a-4-L	471599	5835406	1.72	7.91	9.20	0.46	0.93	296	335	0.02	1.45	0.27	535	1	54	0.3
9925	Nechako Volcanics?	a-4-L	471599	5835406	3.93	16.22	19.50	0.45	3.88	410	449	0.96	3.12	0.81	496	24	99	0.6
9930	Nechako Volcanics?	a-4-L	471599	5835406	2.31	10.24	11.46	0.47	2.11	407	446	0.78	1.90	0.41	496	34	91	0.4
9935	Nechako Volcanics?	a-4-L	471599	5835406	0.06	0.06	0.13	0.31	0.34	319	358	0.08	0.03	0.03	217	133	567	0.2

Standard criteria for rating potential source rocks (Peters 1986)

Rating	Total organic carbon (TOC) wt. %	S1 mg HC/g rock	S2 mg HC/g rock
Poor	0 - .5	0 - .5	0 - 2.5
Fair	.5 - 1	.5 - 1	2.5 - 5
Good	1 - 2	1 - 2	5 - 10
Very good	2+	2+	10+

TOC: Total Organic Carbon (weight per cent), a measure of the amount of organic carbon. S1: the amount of hydrocarbons that can be distilled from one gram of rock (mg/g rock). S2: the amount of hydrocarbons generated by pyrolitic degradation of the kerogen in one gram of rock (mg/g rock). S3: milligrams of carbon dioxide generated from a gram of rock during temperature programming up to 390 °C. S1, S2, and S3 are measures of the quality of the generative potential of the source rock. T_{max} is the temperature at which the maximum amount of S2 hydrocarbons is generated and is an indication of thermal maturity. HI and OI are calculated from S2, S3, and TOC analytical data and are plotted to provide an indication of kerogen type (see Figures 3 and 6).

RESULTS

- The new cuttings yielded Campanian palynomorphs in the Honolulu Nazko well at about 7025 and 7530 ft (2140 and 2295 m), which supports the Campanian age (Riddell et al. 2007) for the greenish shale from drill core at 7364 ft. The new suite also produced Albian to Cenomanian palynomorphs at about 6425 and 6680 ft (1958 and 2036 m), which tightens the depth constraints on the probable thrust fault to between 6680 and 7025 ft (2036 to 2140 m) depth.
- Campanian palynomorphs were identified in a sample of shale cuttings from the 2775 to 2805 m interval in the Can Hunter Nazko well (d-96-E) (telephone communication, Arthur Sweet 2009). A correlation with the Campanian interval at 7115 to 8595 ft (2168 to 2620 m) in the Honolulu Nazko well (a-4-L) is likely.
- The cuttings of the shaly intervals in the volcanic unit near the base of the Honolulu Nazko well (a-4-L) had distinct waxy or petroleum odours and greasy, clumpy textures. The Rock-Eval reruns (Table 3) essentially reproduced the 2002 results of Osadetz et al., confirming that labelling or lab errors were not responsible for the original anomalies. The samples contain Type I and Type II kerogens (Figure 6). The samples are currently undergoing further examination to eliminate the possibility that the Rock-Eval results are an artifact of contamination by drilling materials.
- Preliminary palynological work indicates a Cenomanian or possibly Turonian age for the 450 ft (137 m) thick shale section from 250 to 700ft (76 to 213 m) in the Honolulu Nazko well. A mainly lacustrine depositional environment is indicated by the abundance of algal botryococcous (Arthur Sweet, telephone communication 2009) through most of the interval. Brackish water

TABLE 4. VITRINITE REFLECTANCE DATA. SURFACE SAMPLES ARE FROM JACKASS MOUNTAIN GROUP SANDSTONES FROM THE CHILCOTIN MOUNTAINS ON THE SOUTHERN FRINGE OF THE NECHAKO REGION. SUBSURFACE SAMPLES ARE FROM THE HONOLULU NAZKO WELL (A-4-L).

Sample ID	Sample type	Depth	Vitrinite Reflectance % Ro	Area	Location Easting UTM NAD 83	Location Northing UTM NAD 83	Formation
Field samples							
013JRG07	outcrop	Surface	**0.85**	Yalakom	549597	5662551	Jackass Mtn Gp
52JBM08	outcrop	Surface	**0.78**	Chilko	452262	5711849	"
53JBM08	outcrop	Surface	**1.05**	Yalakom	515269	5676521	"
56JBM08	outcrop	Surface	**1.25**	Yalakom	512925	5677117	"
HFB-08-48	outcrop	Surface	**0.86**	Yalakom	546066	5669559	"
HFB-08-53	outcrop	Surface	**1.27**	Yalakom	555290	5672429	"
HFB-08-55	outcrop	Surface	**1.19**	Yalakom	561982	5657241	"
HFB-08-56	outcrop	Surface	**0.84**	Yalakom	561723	5657447	"
32MMF08B	outcrop	Surface	**1.15**	Yalakom	506737	5681481	"
40EAB08	outcrop	Surface	**0.81**	Red Mtn.	527305	5672151	"
41EAB08	outcrop	Surface	**0.57**	Red Mtn.	527331	5673288	"
42EAB08	outcrop	Surface	**0.68**	Red Mtn.	526845	5675565	"
50EAB08	outcrop	Surface	**0.60**	Red Mtn.	527267	5673367	"
58EAB08	outcrop	Surface	**0.51**	Red Mtn.	527051	5675543	"
Subsurface samples							
Honolulu Nazko a-4-L well	cuttings	350 – 390'	**0.43**	Nazko Valley	471599	5835540	Late K shale
"	cuttings	400 – 440'	**0.44**	"	"	"	"
"	cuttings	450 - 490	**0.46**	"	"	"	"
"	cuttings	500- 540'	**0.47**	"	"	"	"
"	cuttings	550 -590'	**0.49**	"	"	"	"
"	cuttings	600 – 640'	**0.49**	"	"	"	"
"	cuttings	650 -690'	**0.50**	"	"	"	"
"	cuttings	700 – 740'	**0.51**	"	"	"	"
"	cuttings	1010 –1100'	**0.53**	"	"	"	Albian-Cenomanian
"	cuttings	1110 -1200'	**0.52**	"	"	"	"
"	cuttings	1710 -1800'	**0.60**	"	"	"	"
"	cuttings	2240 -2310'	**0.57**	"	"	"	"
"	cuttings	2670 -2690'	**0.54**	"	"	"	"
"	cuttings	3020 -3060'	**0.61**	"	"	"	"
"	cuttings	4010 –4080'	**0.64**	"	"	"	"
"	cuttings	4870 -4890'	**0.57**	"	"	"	"
"	cuttings	6110 -6140'	**0.60**	"	"	"	"
"	cuttings	7180 -7300'	**0.62**	"	"	"	Campanian shale
"	cuttings	7430 -7470'	**0.69**	"	"	"	Campanian shale

and fully marine dinoflagellates are present among the dominantly terrestrial assemblage in the 350 to 400 ft (107 to 122 m) interval, indicating the presence of one or more near-shore marine tongues in the part of the section. Vitrinite reflectance values in this interval range between 0.43% and 0.51% Ro, which are below the oil window.

- New reflectance values for 19 new samples of cuttings from Honolulu Nazko a-4-L are listed in Table 4. The reflectance values range from 0.43% to 0.69%, showing a modest increase in maturity with depth. Samples below 1100 ft (335 m) are in the oil window. The plot of reflectance values against depth for Honolulu Nazko a-4-L contrasts with those of five other Nechako region oil and gas exploration drillholes, all of which show greater maturity increases with depth. Figure 7 illustrates the significant difference in slope between the Honolulu Nazko a-4-L (yellow squares) maturity/depth relationship and those of the other Nechako oil and gas exploration wells. It is interesting that the back-stepping breaks in the plot for the CanHunter d-96-E well (red circles) which seem to indicate post-burial thrust faulting, are not apparent in the Honolulu Nazko a-4-L well, although their wellhead locations are separated

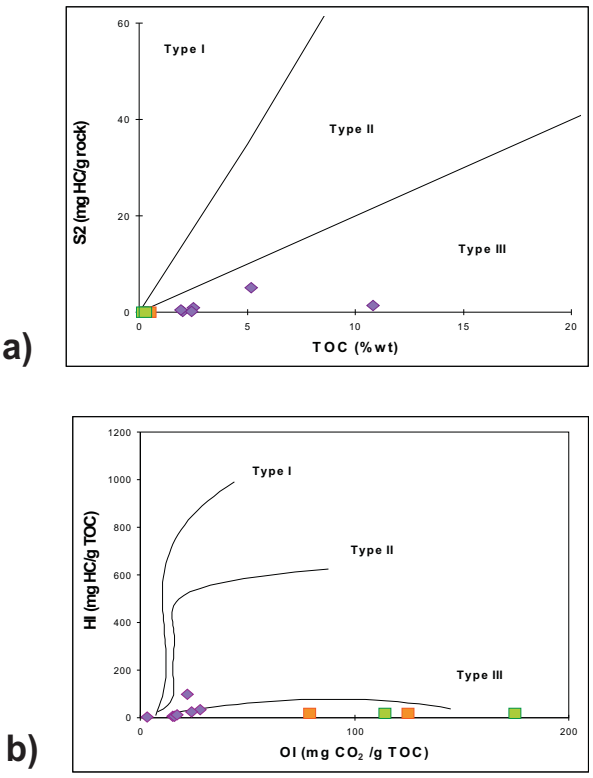


Figure 3. Kerogen classification diagrams of Rock-Eval data from surface samples collected in 2007 and 2008 from the Yalakom and Chilko Lake areas of Mahoney et al. (2009) on the southeastern fringe of the Nechako region. *Purple diamonds represent samples of Jackass Mountain Group from the Yalakom block, green squares are Jackass Mountain Group samples from the Chilko Lake block, and orange squares are Taylor Creek Group samples from the Chilko Lake block. These graphs give an indication of the kerogen type; Type I is very oil-prone, Type II is oil-prone, Type III is gas-prone. These surface samples fall in the Type III (gas-prone) fields. a) S2 versus TOC (total organic carbon); (Langford and Blanc-Valleron 1990); b) HI (hydrogen index) versus OI (oxygen index); (Peters 1986). See Table 3 for definitions of S2, S3, and TOC. HI and OI are calculated from S2, S3, and TOC values. HI = (S2/TOC) × 100 (mg HC/g C_{org}); OI = (S3/TOC) × 100 (mg HC/g C_{org}). c) HI (hydrogen index) versus Tmax.*

by only 1500 m. Also, the maturity values are generally lower (Figure 8) in the Honolulu Nazko well than they are in the CanHunter Nazko well.

- A cuttings sample from the diorite at the bottom of the Honolulu Nazko well has produced a U-Pb date from zircon of about 170 Ma (Middle Jurassic) (Paul O'Sullivan, written communication 2009). Some phases of the Stag Lake suite near Burns Lake (Whalen and Struik 1997) and the Spike Peak stock at Tatla Lake (MacIntyre et al. 2001) have similar ages.

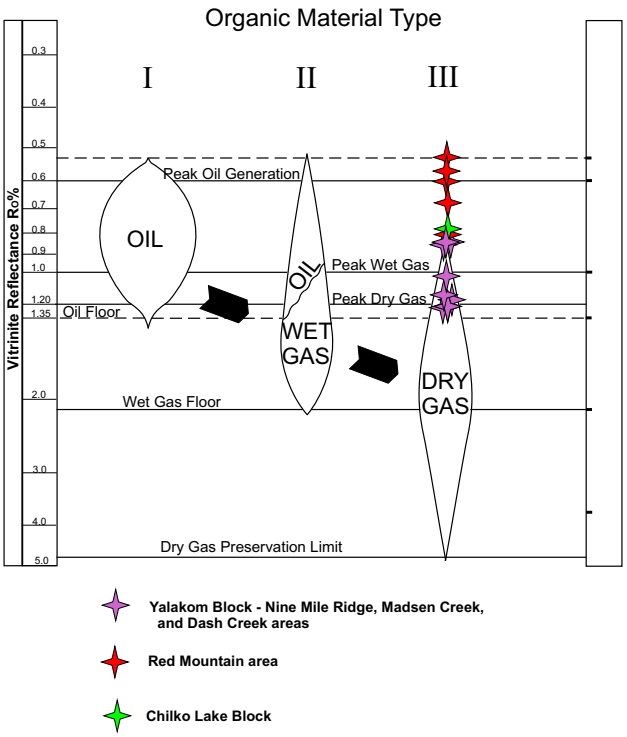


Figure 4. Thermal maturation (Ro) values from vitrinite reflectance data for the Jackass Mountain Group suite, Chilcotin Mountains. *The values are plotted under Organic Material Type III, because Rock-Eval data for the area indicate that the kerogen in these rocks is gas-prone (Type III). The diagram is adapted from Dow (2000). Most of the samples have maturity levels in the range of the oil floor to the peak dry gas zone. The exception is the Red Mountain area, where the samples are undermature for gas generation.*

CONCLUSIONS

- Low permeability (<0.06 mD) values in 5 of 8 samples indicate poor reservoir potential in Skeena Group sandstones from the area south of Houston, British Columbia.
- Jackass Mountain Group sedimentary rocks are exposed along the southeastern fringe of the Nechako region. Vitrinite reflectance thermal maturity data indicate that most samples from the Yalakom block are in the oil to dry gas windows. Six of 9 samples from shale intervals in the Red Mountain and Madsen Lake areas in the Yalakom block yielded TOC values over 1%. Ratios of H, C, and O indicate that the kerogens present are Type III (gas-prone). Three of the 11 sandstone samples from the Yalakom block have moderate permeability and porosity values that could be sufficient for a gas reservoir.
- A potential source bed at 220 to 730 ft (67 to 222 m) depth in the upper part of the Honolulu Nazko well contains Type II kerogens. Palynological data indicate it is Cenomanian or possibly Turonian, and formed in a mainly lacustrine environment. There is evidence of

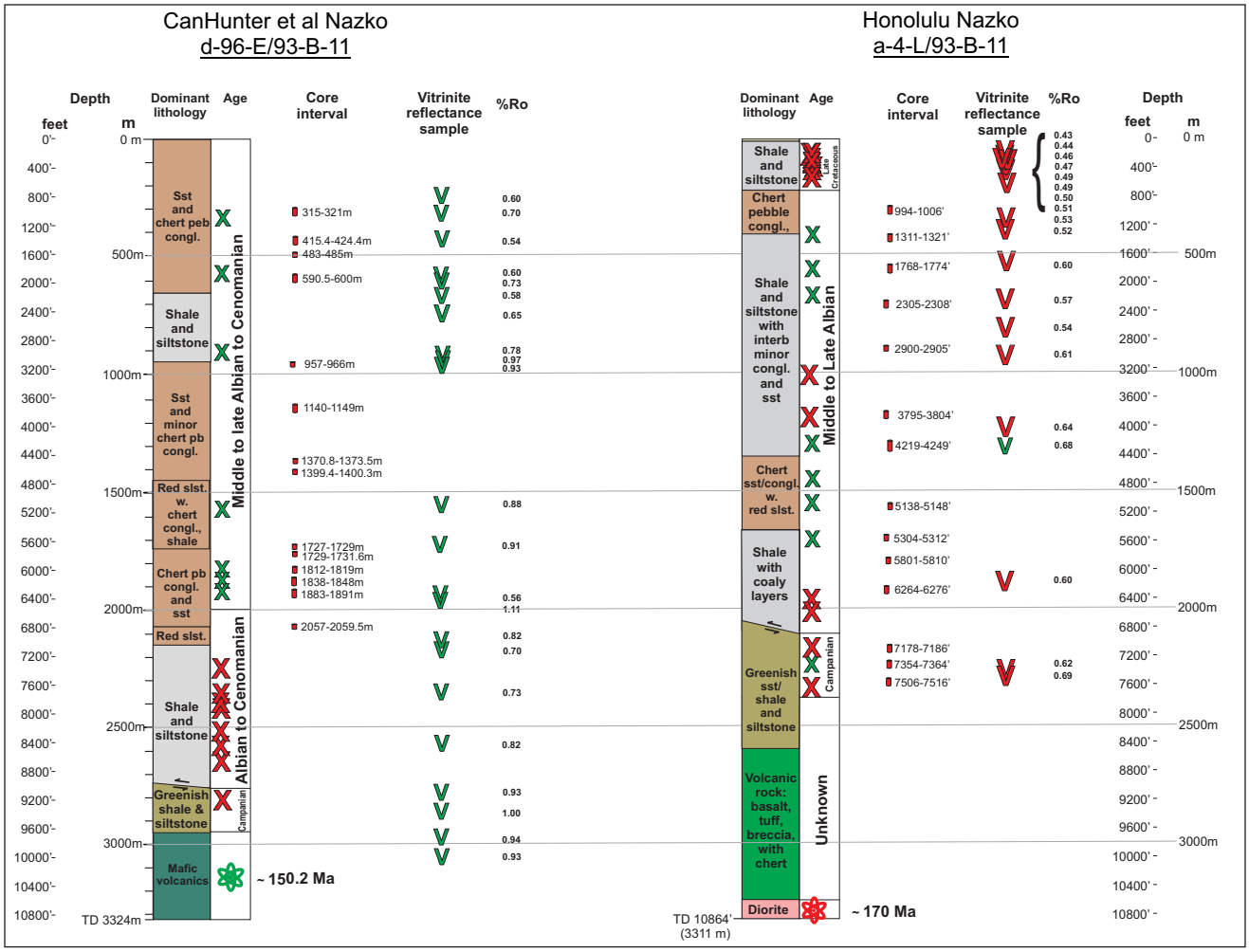
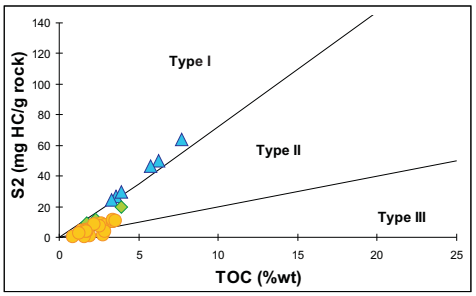


Figure 5. Stratigraphic columns of the two oil and gas exploration wells in the Nazko River valley: Honolulu Nazko (a-4-L), drilled in 1960, and CanHunter Nazko (d-96-E), drilled in 1981. *Locations of new analyses (palynology, vitrinite reflectance, and zircon for radiometric age) are marked in red. Results from samples marked in green were reported by Riddell et al. (2007). Palynology samples are marked with Xs; vitrinite reflectance samples are marked with Vs; radiometric U-Pb dates are marked with the atom symbol.*

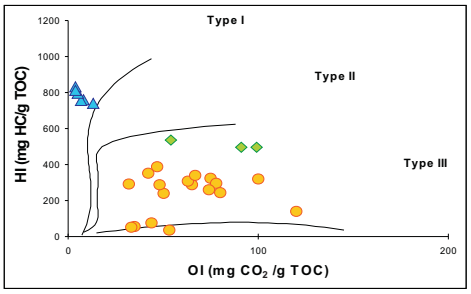
some marine deposition in the 350 to 400 ft (107 to 122 m) interval. It is thermally undermature in this location but could form a good source bed if it is buried deeper elsewhere in the region.

- New palynogical data strengthen the Campanian age estimate for the green shale interval in the Honolulu Nazko well and extend its known stratigraphic extent to 7025 to 7530 ft (2140 to 2295m). Campanian palynomorphs were identified in the CanHunter Nazko well (d-96-E) cuttings in the 2775 to 2805 m interval.
- The wellheads of the two Nazko River wells are only 1500 m apart, but there are significant differences between the stratigraphy of each. The Honolulu Nazko (a-4-L) well is at a lower thermal maturity and shows a lower thermal gradient than CanHunter Nazko (d-96-E) well. The CanHunter Nazko well lacks the Late Cretaceous shale sequence near the top. The thermal gradient, as indicated by vitrinite reflectance and apatite fission track analyses (Riddell et al. 2007), in the CanHunter Nazko well shows significant back-stepping, which suggests thrust faulting. Back-stepping is not apparent in the thermal gradient of the Honolulu Nazko well, neither in the vitrinite reflectance data nor in the thermal alteration index (TAI) of the palynological samples (Riddell et al. 2007). The thrusting that placed the older Albian-Cenomanian rocks over the Campanian in that well must predate the thermal history of the well section recorded in these samples.
- The differences between the two wells implies that, despite their important similarities (both have a 2000 to 2500 m thick Albian-Cenomanian sedimentary section and a Jurassic basement), there are significant differences in their structural and thermal histories. The nature and orientation of a structure or structures between the two wells is a question to be addressed by current interpretations of data from new seismic (Hayward and Calvert 2009) and magnetotelluric (Spratt and Craven 2009) projects.

a)



b)



Rock-Eval samples from the Honolulu Nazko well

Late Cretaceous interval, 220 to 730 ft (67 to 222m)

Rerun samples from the volcanic unit, 6975 to 9935 ft (2125 to 3028 m)

Samples with a petroleum odour

Samples with a waxy odour

Figure 6. Kerogen classification diagrams of Rock-Eval data from subsurface drill cuttings from the Honolulu Nazko well (a-4-L/93-B-11). *Blue triangles and green diamonds represent rerun samples (results in Table 3) from shaly intervals in the volcanic unit between 6975 and 9935 ft. The green diamond samples have a distinctive wax crayon smell and fall along the Type I to Type II kerogen boundary zone. Yellow dots (values from Osadetz et al. 2003) are from the Late Cretaceous shale unit between depths of 220 and 730 feet (67 and 222 m). They have Type II and Type III kerogens. See the caption for Figure 2 for explanation of the diagrams.*

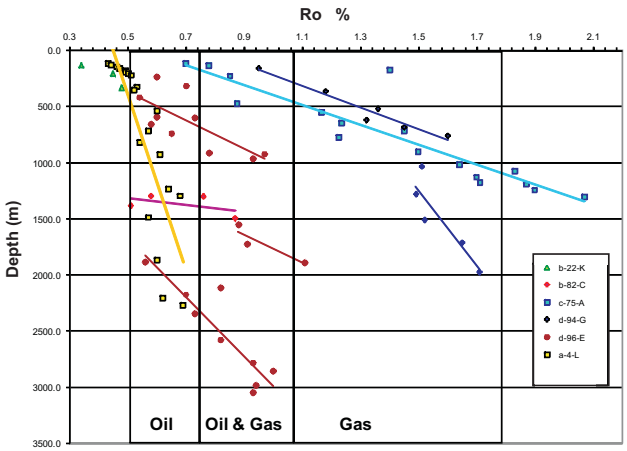


Figure 7: Vitrinite reflectance plotted against depth for Nechako region oil and gas exploration wells. *Data for the Honolulu Nazko well (a-4-L) (yellow squares) are presented in Table 4. Data for the other wells are from Riddell et al. (2007).*

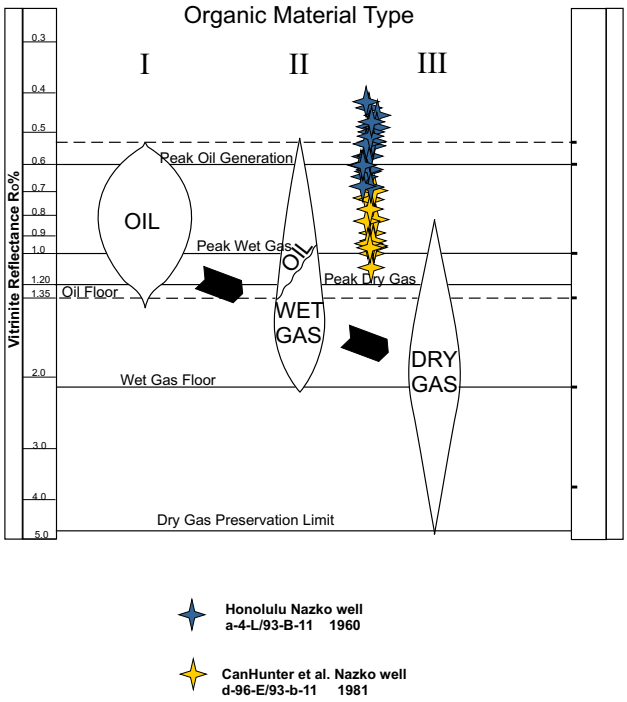


Figure 8. Thermal maturation (Ro) values from vitrinite reflectance data (from Table 4) for the Honolulu Nazko well (a-4-L) (blue crosses). *Data for the CanHunter Nazko well are from Riddell et al. (2007). The maturity range is distinctly lower in the Honolulu Nazko well than in the CanHunter Nazko well. The Honolulu Nazko well is undermature for gas generation. The CanHunter Nazko (d-96-E) well (yellow crosses) values range between the middle of the oil window and the peak dry gas zone. This diagram is adapted from Dow (2000).*

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