Appendix 2

1. U-Pb Geochronology

Three samples of felsic tuff within the Patry and Exshaw formations were obtained from the Chevron Woodside Patry b-23-K/94-O-5 and Nexen Duned a-38-B/94-N-8 and recovered zircons were analyzed at the laboratories of the Pacific Centre for Isotopic and Geochemical Research within the Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia using chemical abrasion thermal ionization mass spectrometry (CA-TIMS).

1.1. U-Pb Analytical Techniques

CA-TIMS procedures described here are modified from Mundil et al., 2004, Mattinson, 2005 and Scoates and Friedman, 2008. After rock samples have undergone standard mineral separation procedures zircons are handpicked in alcohol. The clearest, crack- and inclusion-free grains are selected, photographed and then annealed in quartz glass crucibles at 900˚C for 60 hours. Annealed grains are transferred into 3.5 mL PFA screwtop beakers, ultrapure HF (up to 50% strength, 500 mL) and HNO3 (up to 14 N, 50 mL) are added and caps are closed finger tight. The beakers are placed in 125 mL PTFE liners (up to four per liner) and about 2 mL HF and 0.2 mL HNO3 of the same strength as acid within beakers containing samples are added to the liners. The liners are then slid into stainless steel Parr™ high pressure dissolution devices, which are sealed and brought up to a maximum of 200˚C for 8-16 hours (typically 175˚C for 12 hours). Beakers are removed from liners and zircon is separated from leachate. Zircons are rinsed with >18 MΩ.cm water and subboiled acetone. Then 2 mL of subboiled 6N HCl is added and beakers are set on a hotplate at 80˚-130˚C for 30 minutes and again rinsed with water and acetone. Masses are estimated from the dimensions (volumes) of grains. Single grains are transferred into clean 300 mL PFA microcapsules (crucibles), and 50 mL 50% HF and 5 mL 14

N HNO3 are added. Each is spiked with a 233-235U-205Pb tracer solution (EARTHTIME ET535), capped and again placed in a Parr liner (8-15 microcapsules per liner). HF and nitric acids in a 10:1 ratio, respectively, are added to the liner, which is then placed in Parr high pressure device and dissolution is achieved at 220˚C for 40 hours. The resulting solutions are dried on a hotplate at 130˚C, 50 mL 6N HCl is added to microcapsules and fluorides are dissolved in high pressure Parr devices for 12 hours at 180˚C. HCl solutions are transferred into clean 7 mL PFA beakers and dried with 2 mL of 0.5 N H3PO4. Samples are loaded onto degassed, zone-refined Re filaments in 2 mL of silicic acid emitter (Gerstenberger and Haase, 1997).

Isotopic ratios are measured with a single collector VG 54R thermal ionization mass spectrometer equiped with analogue Daly photomultiplier. Analytical blanks are 0.1 pg for U and up to 2.5 pg for Pb. U fractionation was determined directly on individual runs using the EARTHTIME ET535 mixed 233-235U-205Pb isotopic tracer and Pb isotopic ratios were corrected for fractionation of 0.25 ± 0.04%/amu, based on replicate analyses of NBS-982 reference material and the values recommended by Thirlwall (2000). Data reduction employed the excel-based program of Schmitz and Schoene (2007). Standard concordia diagrams were constructed and regression intercepts, weighted averages calculated with Isoplot (Ludwig, 2003). Unless otherwise noted all errors are quoted at the 2 sigma or 95% level of confidence. Isotopic dates are calculated with the deay constants l238=1.55125E-10 and l235=9.8485E-10 (Jaffe et al, 1971) and a 238U/235U ratio of 137.88. EARTHTIME U-Pb synthetic solutions are analysed on an on-going basis to monitor the accuracy of results. H. Lin did the mineral separation. T. Ockerman conducted activities in the clean lab and H. assisted with mass spectrometry.

2. Lithogeochemistry

Samples of Besa River Group core from the Nexin Dunedin a-38-B/94-N-8 well were collected approximately every 1m and analyzed for major, minor, trace and rare earth elemental composition at the laboratories of Bureau Veritas in Vancouver through inductively coupled plasma mass spectrometry of a sample digested by HNO_3, $HClO_4$, HF and HCl. This digestion is only partial for some S, Cr and Ba minerals and some oxide minerals of Al, Hf, Mn, Sn, Ta, Zr. In addition, volatilization during fuming may result in some loss of As, Sb and Au. See: http://acmelab.com/.

Major oxide compositions were calculated by the senior author from elemental abundances. As this analytical package does not analyze for silica, this oxide was calculated through subtraction of other major oxides together with sulphide, organic and mineral carbon abundances as described in Wang et al., 2016.

3. Rock-Eval pyrolysis

Rock samples of Besa River Group core from the Nexin Dunedin a-38-B/94-N-8 well were collected approximately every 1m and pyrolyzed using a Rock-Eval 6 apparatus at the Geological Survey of Canada in Calgary, AB. This technique evaluates oil and gas shows, oil and gas generation potential, and thermal maturity, and identifies organic matter type (Espitalie et al. 1985a, b, 1986; Peters, 1986; Tissot and Welte, 1978, p. 443-447). This instrument uses a ramped temperature pyrolysis technique whereby a small amount of sample (70 -100 mg) is heated in an inert atmosphere (helium or nitrogen) and combusted with air to obtain several key geochemical parameters relating to the hydrocarbon potential of the rock: the total organic carbon (TOC), type or quality of organic matter and level of maturity (Peters 1986; Lafargue et al. 1998; Behar et al. 2001). Rock-Eval/TOC is a useful screen for recognizing hydrocarbon sources and stained rock types. The analysis gives five parameters: S1, S2, S3, TOC and Tmax.

The S1 parameter measures free or adsorbed hydrocarbons volatilized at moderate temperatures (300ºC). S2 measures the hydrocarbons liberated during a ramped heating (300-650ºC at 25ºC/min.). The S3 parameter measures organic CO_2 generated from the kerogen during rapid heating (300-390ºC at 25ºC/min.). Milligrams product per gram rock sample, the equivalent to kilograms per tonne, is the measure of all these parameters. Total organic carbon (TOC) is measured in weight per cent. Tmax, the temperature corresponding to the S2 peak maximum temperature, is measured in ºC.

Rock-Eval results correlate to other techniques (Espitalie et al., 1985a, b, 1986; Tissot and Welte, 1978). Source rock potential is sensitive to lithology, TOC and S2 values (Tables 1 and 2). It is common practice to rate carbonate rocks with lower TOC comparable with richer clastic rocks. Extractable HC yields from leaner carbonate rocks are comparable to richer clastic rocks (Tissot and Welte, 1978, p. 430; Gehman, 1962). The organic matter associated with carbonate rocks is often more hydrogen-rich and thermally labile than that in fine-grained clastic rocks. As a result, more TOC in carbonate rocks may be transformed into bitumen compared with average clastic source rocks of comparable maturity.

Rock-Eval/TOC parameters have significance only above threshold TOC, S1 and S2 values. If TOC is less than < 0.3 wt. % then all parameters have questionable significance and the experiment suggests no potential. Oxygen Index (OI), S3/TOC, has questionable significance if TOC is < 0.5 wt. %. Both Tmax and Production Index (PI = S1/(S1+S2)), have questionable significance if S1 and S2 values are < about 0.2 mg HC/g rock. Results can be affected by mineral matrix effects. These either retain generated compounds, generally lowering the S1 or S2 peaks, while increasing Tmax, or by liberating inorganic CO_2 and increasing S3 and OI. These

effects are important if TOC, S1 and S2 are low. OI values greater than 150 mg/g TOC suggest either low TOC or a mineral matrix CO_2 contribution during pyrolysis.

Table 1: Standard criteria for rating potential source socks based on TOC values.

Rating	**Wt. %TOC**	**Wt. %TOC**
	In shales	**In carbonates**
Poor	0.00 - 0.50	0.00 - 0.12
Fair	0.50 - 1.00	0.12 - 0.25
Good	1.00 - 2.00	0.25 - 0.50
Very Good	2.00 - 4.00	0.50 - 1.00
Excellent	>4.00	>1.00

Table 2: Standard criteria for rating potential source rocks based on S2 values.

Rating	**S2 mg HC/g**
Poor	Less than 2.00
Fair	2.00 - 5.00
Good	Greater than 5.00

Results reported in this report were obtained from one of several Rock-Eval 6 apparatus at the Geological Survey of Canada. This instrument is an improvement over the Rock-Eval 2 apparatus and provides greater sensitivity and more parameters on rock composition (see Behar et al. 2001 and Lafargue et al. 1998). For comparison purposes, OI as reported by the Rock-Eval 2 instrument is equitable to the $OICO_2$ as obtained by the Rock-Eval 6 machine.

4. δ^{13} organic carbon isotope analyses by Continuous-Flow Isotope Ratio Mass Spectrometry

Organic carbon isotope analyses were performed at the Isotope Science Laboratory of the University of Calgary (http://ucalgary.ca/uofcisl/). The following analytical procedure is summarized from a document that can be obtained from the Isotope Science Laboratory website. Mineral carbon in the sample was removed at the Geological Survey of Canada laboratories through the addition of HCl acid prior to analysis. Samples were washed with distilled water, dried and pulverized in an agate mill. The samples were acid washed with concentrated HCl and then washed again with distilled water after being acidized.

Analyses of $\delta^{13}C$ and weight per cent C were accomplished using Continuous Flow-Elemental Analysis-Isotope Ratio Mass Spectrometry (CF-EA-IRMS) technology at the University of Calgary. This process can simultaneously analyze carbon and nitrogen isotopic ratios. A Thermo DeltaV+ mass spectrometer is interfaced with either an Elementar Isotope CUBE or Costech 4010 elemental analyzer. Sample materials are packed in tin cups, which are dropped by auto sampler onto a quartz tube combustion column. The temperature of this column is maintained at ~1000 ^{o}C and 'flash-combustion' is achieved by injecting a pulse of O_2(gas) exactly at the time of sample drop. The gases are then swept by the helium carrier stream through a reduction furnace at ~650 ^{o}C, thus reducing NO_x species to N_2(gas). Gas chromatography separation of N2 and CO_2 is achieved before the gas stream is leaked through a Conflo-IV, open split into the ion source of the mass analyzer. $\delta^{13}C$ values are determined by comparing the respective sample peak areas to reference gas peaks also inlet through the open split.

Internal lab standards are used at the beginning, between (every 5th) and the end of each sample tray to correct for instrument drift and to normalize the data to internationally accepted

standards. All $\delta^{13}C$ values are reported relative to the V-PDB scale. Internal lab standards have been characterized against the International Standards listed above and are re-checked periodically. USGS LIMs is used for drift correction, normalization and data management. (http://water.usgs.gov/software/LIMS/).