Appendix 1: Analytical methods

The sections were measured using a 1.5 m staff. Semi-continuous chip samples for whole rock geochemistry, Rock-Eval and X-ray diffraction analysis were acquired across 2 m intervals. The samples were crushed and homogenized before submission for analysis. Separate samples were acquired for vitrine reflectance (reflective light thermal maturation determination).

A.1.1. Rock-Eval pyrolysis

Rock samples were pyrolyzed using a Rock-Eval 6 apparatus at the Geological Survey of Canada (Calgary). This technique evaluates oil and gas shows, oil and gas generation potential, and thermal maturity, and identifies organic matter type (Tissot and Welte, 1978; Espitalie et al., 1985a, b, 1986; Peters, 1986). 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 (300°C). S2 measures the hydrocarbons liberated during a ramped heating (300-650°C at 25°C/min.). The S3 parameter measures organic CO_2 generated from the kerogen during rapid heating (300-390°C at 25°C/min.). Milligrams product per gram rock sample, the equivalent to kilograms per tonne, is the unit measure of all these parameters. Total organic carbon is measured in weight per cent. Tmax, the temperature corresponding to the S2 peak maximum temperature, is measured in ^{o}C. Rock-Eval results correlate to other techniques (Tissot and Welte, 1978; Espitalie et al., 1985a, b, 1986). 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 siliciclastic rocks. Extractable hydrocarbon (HC) yields from leaner carbonate rocks are comparable to richer siliciclastic rocks (Gehman, 1962; Tissot and Welte, 1978).The organic matter within carbonate rocks is commonly more hydrogen-rich and thermally labile than that in fine-grained siliciclastic rocks. As a result, more TOC in carbonate rocks may be transformed into bitumen compared to average siliciclastic source rocks of comparable maturity.

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

Rock-Eval/TOC parameters have significance only if 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 approximately <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. Oxygen Index values greater than 150 mg/g TOC suggest either low TOC or a mineral matrix CO_2 contribution during pyrolysis.

Results reported in Appendices 2 and 3 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 Lafargue et al., 1998; Behar et al., 2001). For comparison purposes, OI as reported by the Rock-Eval 2 instrument is equivalent to the $OICO_2$ obtained by the Rock-Eval 6 machine.

A.1.2. Lithogeochemistry

Samples were cleaned, crushed and split at the British Columbia Ministry of Energy and Mines. All samples, duplicates, and standards were analyzed at Acme Analytical Laboratories Ltd. (Vancouver) for major, trace, and rare earth element abundances. Every twentieth sample analyzed was a duplicate; the USGS SDO-1 Devonian Ohio shale (Kane et al., 1990) was used as a geochemical standard. Samples were pulverized at Acme Analytical Laboratories Ltd. in a mild steel mill and sieved to 200 mesh. A quartz wash was completed before each sample was milled. Major element (Si, Al, Fe, Ca, Mg, Na, K, Mn, Ti, P, Cr and Ba) concentrations were determined on a 0.2 g sample by inductively coupled plasma-emission spectroscopy (ICP-ES) following a lithium metaborate – tetraborate fusion and dilute nitric acid digestion. Rare earth and refractory element abundances (Ba, Be, Co, Cs, Ga, Hf, Nb, Rb, Sc, Sn, Sr, Ta, Th, U, V, W, Y, Zr, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) were determined from a 0.2 g sample by induced coupled plasma mass spectroscopy (ICP-MS) after a lithium metaborate-tetraborate fusion and nitric acid digestion. Precious and base metals (Au, Ag, As, Bi, Cd, Cu, Hg, Mo, Ni, Pb, Sb, Se, Tl, and Zn) concentrations were determined from a 0.5 g split digested in nitric-hydrochloric acid solution and analyzed by ICP-MS. Total carbon and sulphur were determined by a Leco Carbon/Sulphur analyzer whereby a 2 g sample was combusted and liberated CO_2 and SO_2 were measured via an infrared detection cell.

A.1.3. Gamma ray spectrometry

Natural gamma ray emissions from the outcrop were acquired with a RS-230 BGO Super-Spec hand-held gamma ray spectrometer produced by Radiation Solutions Inc. Outcrop data were gathered at 1 m intervals with the flat, front face of the instrument (containing the detector)

placed against a flat rock surface. The attitude of the instrument was parallel to bedding surfaces and care was taken so that the measuring surface was not recessed. Data were acquired for 60 seconds after which the instrument converted measured gamma ray energy levels into concentrations of K (%), Th (ppm) and U (ppm). Average total counts were also recorded.

A.1.4. Vitrinite reflectance (thermal maturity)

Due to the rate of coalification reactions and percent increase in the reflectance in oil (%Ro) of huminite, vitrinite and bitumen (Jacob, 1989) with increasing temperature, these macerals provide an indirect geothermometer for evaluating the thermal conditions during sediment burial. Standard procedures for organic petrology based on Mackowsky (1982) were generally followed. Washed core cuttings, core, and outcrop samples were prepared in a similar way by crushing them into 1-5 mm particulates, although many were ~1 cm cubes. The samples were then mounted in a 2.54 cm mold using two parts epoxy, and then polished using four types of polishing material. Random reflectance (Rom) measurements were determined using a Leitz reflected light microscope with a 50X oil immersion objective and white (halogen; 546 nm) and fluorescent (HBO 100 W) light sources. The %Ro measurements were taken by a Leitz MPV II – COMBI photometer system mounted on top of the microscope (and attached to a pc-controller system). Reflectance was calibrated using Schott precision glass standards with 0.506, 1.025, and 1.817 %Ro refractive index. The microscope was calibrated before and mid-way through each analysis in accordance with standard procedures outlined in International Committee for Coal Petrology (1995), Mackowsky, (1982), and Bustin et al. (1983). The oil used was halogen free/low fluorescence with a refractive index of ne = 1.518 at 23°C. Reflectance measurements were made on vitrinite, bituminite, and bitumen macerals together with identified alginite- and sporinite- derived macerals. In the absence of vitrinite, vitrinite equivalent (%Ro equivalent) was calculated using the measured reflectance of primary bitumen (%Ro bitumen) and Jacob's (1989) equation (if applicable). For vitrinite, huminite, eu-ulminite B and telovitrinite A are the preferred macerals for reflectance measurement.

A.1.5. X-Ray diffraction

The mineralogy of bulk materials and clay-size separates was determined by X-ray powder diffraction analysis (XRD) at the Geological Survey of Canada (Ottawa). Suspensions (in water) of the samples were pipetted onto glass slides and air-dried overnight to produce oriented mounts. X-ray patterns of the air-dried samples were recorded on a Bruker D8 Advance Powder Diffractometer equipped with a Lynx-Eye Detector, with Co Kα radiation set at 40 kV and 40 mA. The samples were also X-rayed following saturation with ethylene glycol and heat treatment.

Initial mineral identification was made using EVA (Bruker AXS Inc.) software and comparisons to reference mineral patterns using Powder Diffraction Files (PDF) of the International Centre for Diffraction Data (ICDD) and other available databases. Quantitative analysis was carried out using TOPAS (Bruker AXS Inc.), a PC-based program that performs Rietveld refinement (RR) of XRD spectra. This is based on a whole pattern fitting algorithm. It relies on having particular mineralogical structure files (.cif) such that the reference minerals are as close a match as possible to the unknown.

All samples were further pulverized in a McCrone mill to 5-10 µm, which is more appropriate for RR. All the samples were then prepared as pressed powder, randomly oriented mounts. Sample FF10-313 was also run as a smear mount to verify if swelling clays were present.

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