Open File 2011-3

Rock-Eval and lithogeochemistry of Early to Middle Jurassic black clastic rocks within the Intermontane Basins of British Columbia.

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General:

This open file present lithogeochemistry and Rock-Eval analysis of over 225 outcrop samples of Early to Middle Jurassic clastic rocks from the Intermontane Basins of British Columbia. Parts of the data presented in this open file have been interpreted within Ferri (2011). The reader is referred to Ferri (2011) for the regional geological synopsis in the vicinity of the data sets. The relative stratigraphic position of samples within the Spatsizi Formation in the Joan Lake area are shown in one of the data spread sheets. These elevation numbers were used to construct the elemental concentration profiles across the Spatsizi Formation shown in Ferri (2011).

Notes regarding Anhydrous Pyrolysis (Rock-Eval):

Rock samples were pyrolyzed using Rock-Eval 6 apparatus at the laboratories of the Geological Survey of Canada in Calgary, AB. This technique evaluates oil and gas shows, oil and gas generation potential, 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 also 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 sources and stained lithologies. The analysis gives five parameters: S1, S2, S3, TOC and Tmax. The S1 parameter measures free or adsorbed hydrocarbons volatilized at moderate temperatures (300^{o}C). S2 measures the hydrocarbons liberated during a ramped heating (300-650^{o}C at 25^{o}C/min.). The S3 parameter measures organic CO_2 generated from the kerogen during rapid heating (300-390^{o}C at 25^{o}C/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 ^{o}C.

Rock-Eval results correlate to other techniques (Espitalie et al., 1985; 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. 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 vaules.

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

Results reported in this open file 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.

When considering the Rock-Eval data provided in this report special care should be exercised in the interpretation and attribution of significance to a number of standard parameters, specifically those associated with the S2 peak, including the S2 peak, Tmax, Hydrogen Index and Production Index. For many of the samples the S2 yield is zero and for many others the S2 yield is less than the normal threshold of 0.3. We observe that better TOC and S2 values are commonly associated with the Junction Creek unit (see results table), such that some additional interpretational significance might be associated with those samples.

Notes on Lithogeochemistry

Samples were cleaned, crushed and split at the BC Ministry of Energy and Mines. All samples, duplicates and standard were analyzed at Acme Analytical Laboratories Ltd. in Vancouver, BC for major, trace and rare earth element abundances. Samples were pulverized at Acme Analytical Laboratories Ltd. in a mild steel mill and sieved to 200 mesh. Quartz was processed through the mild steel mill prior to the milling of each sample. Major element (Si, Al, Fe, Ca, Mg, Na, K, Mn, Ti, P, Cr and Ba) concentrations were determined on a 0.2g sample by inductively coupled plasma emission spectroscopy (ICP-ES) subsequent to 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 0.2g 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 2g sample was combusted in an oxygen atmosphere and liberated CO_2 and SO_2 were measured via an infrared detection cell.

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