

Methods

A total of 641 samples were analyzed and include core samples (wells c-74-G/94-b-09, d-48-A/94-b-09, 02-30-070-24W5, 16-17-083-25W6, and 11-20-082-02W6) and outcrop samples (Ursula Creek, British Columbia; Fig. 1). The wells and outcrop were chosen to create a transect perpendicular to the Triassic paleoshorline. The sampling interval was 0.5 or 1 m, depending on the length of the well or outcrop. Sampling at this resolution will inherently miss laminar-scale as well as thin-bed variation; however, because our study is at the basin-scale, we feel that the general, basin-wide trends will be captured sufficiently at this interval of sampling. Sample size varied between 2 and 5 cm², but only 0.25 g is required for analysis by lithium metaborate fusion.

As sample collection and analysis took place over a significant length of time, samples were analyzed in batches at two different laboratories (Chemostrat Laboratories and Bureau Veritas Mineral Laboratories). Samples from wells c-74-G/94-b-09, d-48-A/94-b-09, 02-30-070-24W5, 16-17-083-25W6 and the Ursula Creek outcrop were analyzed using both inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma optical emission spectrometry (ICP-OES) at Chemostrat laboratories in Houston, Texas, a laboratory accredited to ISO 17025:2005 (equivalent to ISO 9000). ICP-MS analysis was conducted using a Thermo Scientific XSERIES 2 mass spectrometer while ICP-OES analysis was completed using a Scientific iCAP 7000 Series ICP-OES mass spectrometer. Outcrop samples were selected to exclude surface weathering and only fresh, unexposed rock was sampled.

Following procedures outlined in Hildred *et al.* (2010), all samples were cleaned using water and solvent to remove surface contamination. Subsequently, samples analyzed

at Chemostrat laboratory were pulverized using an agate mortar and subjected to a Li-metaborate digestion (Jarvis and Jarvis, 1992). Major elements analyzed for include: SiO₂, TiO₂, Al₂O₃, Fe₂O₃, MgO, MnO, CaO, Na₂O, K₂O, and P₂O₅. Data was also collected for 25 trace elements (Ba, Cr, S, Sc, Sr, Zn, Zr, Be, V, Co, Ni, Cu, Ga, Rb, Y, Nb, Mo, Sn, Cs, Ta, W, Tl, Pb, Th, and U) and 14 rare earth elements (REE: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Ho, Dy, Er, Tm, Yb, and Hf). Major-element data and high-abundance trace elements (e.g., Cr, Sc, Sr, and Zr) were determined using ICP-OES. Precision, measured by running select samples in triplicate, is estimated to be $\pm 2\%$ for major elements run on ICP-OES for the major-element data, and approximately $\pm 3\%$ for high abundance trace elements. Low-abundance trace element data collected via ICP-MS, is estimated to have a precision of $\pm 5\%$. The accuracy, measured by using an internal standard, of major element analysis is $\pm 1\%$. Additionally, in order to assess external reproducibility, 11 batches of five certified reference materials were analyzed in duplicate. The associated two-sigma uncertainty is 5-7% for major elements and 7-12% for trace elements. Trace element accuracy ranges from $\pm 3-7$ ppm, decreasing with higher abundance.

Samples from well 11-20-082-02W6 were analyzed by Bureau Veritas Mineral Laboratories (formerly Acme labs) using LiBO₂ digestion followed by ICP-MS conducted with a Perkin Elmer Elan 6000 ICP mass spectrometer (SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, MnO, Cr₂O₃, Sc, Ba, Be, Co, Cs, Ga, Hf, Nb, Rb, Sn, Sr, Ta, Th, U, W, Zr, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu). Detection limits vary from 0.01 to 1 ppm. Error values and reproducibility for geochemical data (by element) from this lab are available within Rukhlov and Pawlowicz (2011).

Select samples (18 in total) from 02-30-070-24W5 were analyzed by a Bruker AXS D8

Advance X-ray Diffractometer at SGS Mineral Services Lakefield, Ontario, a lab accredited to ISO/IEC 17025. A Co radiation source operating at 40 kV and 35 mA was used. Scans were taken stepwise at 0.02° intervals, with a step time of 0.2s, and a 2θ range from $3-70^\circ$. Spectral interpretations were made using PDF2/PDF4 powder diffraction databases issued by the International Center for Diffraction Data (ICDD), and DiffracPlus Eva® software. The detection limit is 0.5-2% (dependent on crystallinity).

A statistical evaluation of the correlation between mineralogical and elemental data was conducted using Pearson product-moment correlation (PPMC) and eigenvector analyses (EA) on DataDesk®6.3.1. Principal component analysis was used as an indicator for mineralogy during chemostratigraphic analysis (Pearce *et al.*, 2005; Svendsen, *et al.*, 2007; Ellwood *et al.*, 2008; Ratcliffe *et al.*, 2010, 2015). Additionally, to investigate sediment provenance, abiotic carbonate input and hydrothermal influence, plots of La/Sm versus Yb/Sm, $\log(\text{Fe}_2\text{O}_3/\text{K}_2\text{O})$ and $\log(\text{SiO}_2/\text{Al}_2\text{O}_3)$, Th/Sc versus Cr/Th, and Sr versus Mg cross-plots were created using DataDesk®6.3.1 and Microsoft Excel ®2010. Plots of Fe/S and P/Fe were also produced using this software, as well as rare earth element plots (REE plots) normalized to chondrite abundance.

Chemostratigraphic packages were defined using principle component analysis and cluster analysis on the most complete core data set (16-17-083-25W6), which was used as the type section. In total, 84 variables were considered, as summarized in Table I. The variables used fall into eight categories: the first and second categories, referred to as oxides and trace elements comprise the unaltered data provided by the lab; the third category, oxide elements, contains the calculated elemental portion of the oxides converted to ppm; the final categories, indicators, comprise ratios of elements or oxides.

The 84 variables have a variety of relationships and correlations to one another. To condense the data set and reduce the redundancy between variables, principal component analysis was applied (Johnson and Wichern, 1988; Schlens, 2014). This method is a multivariate transformation that reduces the dimension of the data set while retaining most of the variance of the original data. Supplementary Table VII shows a summary of the first ten principal components, the variance in the data set explained by each component, and the cumulative percentage of the variance explained. The first six components account for over 80% of the variance; these six were retained and used for cluster analysis.

The six principal components were used with depth as a seventh variable to divide the 238 data points into clusters (Tan *et al.*, 2006). Hierarchical clustering was used to merge the data points into clusters, with the multidimensional distance between clusters calculated by Ward's method (Ward, 1963). Supplementary Figure 30 defines the relationship between the number of clusters and the corresponding similarity between the clusters. As more clusters are merged with one another, more dissimilar data points must be combined and there is therefore less similarity between the remaining clusters. Supplementary Figure 30 highlights an inflection point at 12 clusters, where reducing the number of clusters rapidly decreases similarity. For this reason, 12 clusters were retained in the results. Although only occurring in the basal data point (and thus statistically insignificant), a thirteenth division was added based on the published contact between the Permian Belloy Formation and the Montney Formation in this data set (Golding *et al.*, 2014).

Chemofacies were then analyzed and summarized using clay indicator ratios (Cr/Sc, Zr/La, Zn/Sc, SiO₂/Al₂O₃, Ga/Rb, K₂O/Al₂O₃, K₂O/Rb, Na₂O/Al₂O₃, Rb/Al); provenance

ratios (Ni/Al, Cr/Al, Th/Sc, Ti/Zr, MgO/Al₂O₃, and Ti/Nb); detrital input indicators (TiO₂/Al₂O₃, TiO₂/K₂O, Lu/Hf, Sc/Zr) and mineralogical indicators (P₂O₅/Al₂O₃, Cr/Nb, Lu/Zr, and Cr/Zr). Further details of each are provided in the following section. An average value of each ratio was determined from the type section. These overall average values were compared to the averaged values generated from within each chemofacies in order to make interpretations. Due to the low elemental immobility, and the relation to detrital input, subsequent data sets were correlated primarily using the signatures of Sc/Zr, Lu/Hf, and Zr/La (see the section entitled 'Elemental Indicators' for a more detailed explanation of the ratios used in this study).