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Whole rock geochemical analysis of a low accommodation fluvial reservoir: an example from the (Lower Cretaceous) Basal Quartz, Southern Alberta

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Abstract

Whole rock geochemical analysis of ninety core samples from the Basal Quartz (BQ) in six wells from southern Alberta has allowed the concentrations of 47 elements to be determined for each sample. These data are used to geochemically define three component units of the BQ, namely the Horsefly, the BAT and the Ellerslie. The results demonstrate that the technique of chemostratigraphy (or chemical stratigraphy) can be used to clearly differentiate these units.

The BQ in southern Alberta is a prolific hydrocarbon reservoir comprising a complex sequence of sandstones and silty claystones. Due to its low accommodation, fluvio-estuarine setting, robust interwell correlation of the component units is required to fully exploit the reservoir. Previously, detailed petrographic study of the coarse grained components has been used to aid with regional mapping of the reservoir. The petrographic work allows definition of two cycles within the BQ and three component units of the upper cycle (the Horsefly, BAT and Ellerslie). Once defined, the distribution of these reservoir sandstones can be regionally mapped. Chemostratigraphy, using whole rock geochemical data, is a method that enables characterisation and correlation of the fine-grained component of the BQ. The geochemical data obtained for this paper demonstrate that the silty claystones from the Horsefly, the BAT and the Ellerslie each have sufficiently distinctive elemental compositions to allow their differentiation. The key elements used for this differentiation, such as Al_2O_3, Na_2O, K_2O, P_2O_5, Rb, Zr, Cr and Nb, are related to changes in detrital clay and heavy mineralogy.

Introduction

The Lower Cretaceous Basal Quartz (BQ) is an informal term for the Lower Mannville succession, which together with the "Ostracode", forms the Lower Mannville Formation (Fig. 1). In the study area, southern Alberta, the BQ is thin (<100m), and is characterized by a complex stratigraphy punctuated by multiple unconformities (Zaitlin *et al*, 2002; Ardies et al., 2002). This chemostratigraphic study has concentrated on the fine-grained facies of the Horsefly, BAT and Ellerslie units, which form the upper of two cylces within the Lower Mannville Formation (Fig 1). The main aim of this study is to demonstrate that significant geochemical variation can be detected between silty claystones of the Horsefly, BAT and Ellerslie units.

Conventional cores form six wells were selected for chemostratigraphic analysis (Table A). When sampling the core, only apparently homogenous silty claystone chips approximately 2-3cm^3 were selected. By studying intervals in wells where the stratigraphy had already been determined by detailed petrographic studies (Zaitlin *et al*. 2002), it is shown that the associated finer grained facies of the Horsefly, BAT and Ellerslie units exhibit significantly different elemental compositions. Geochemical profiles, binary and ternary diagrams are the most effective way to express these variations (Fig 2-4).

Chemostratigraphy, or chemical stratigraphy, involves the characterisation and correlation of strata using major and trace element geochemistry. For this study, data for a total of 47 elements (10 major elements, 24 trace elements and 13 rare earth elements) have been determined using inductively coupled plasma atomic emissions spectrometry (ICPAES) and inductively coupled plasma mass spectrometry (ICP-MS). The sample preparation and analytical procedures used are detailed in Pearce *et al* (1999) and Jarvis and Jarvis (1995).

TABLE A. Total number of silty samples analyzed from the each of the study wells with the stratigraphic unit assignment.

Well	Unit	Sample no.
10-29-36-27 W4	Ellerslie	11
3-30-37-27 W4	Ellerslie	10
6-11-26-28 W4	BAT	13
1-35-1-20 W4,	Horsefly	10
2-4-1-17 W4	Horsefly	27
7-9-11-16 W4	Horsefly	19
Total samples		*90*

Geochemical differentiation

Fig 2 displays "synthetic" geochemical profiles that have been constructed by plotting samples in correct stratigraphic order, but with no reference to absolute depth. The samples displayed on Fig 2 are from the Horsefly (well 2-4-1-17 W4), the BAT (well 6-11-26-28 W4) and the Ellerslie (well10-29-36-27 W4). Although samples from these units are lithologically similar, the geochemical profiles show that primary geochemical differences exist between each unit thereby allowing characterisation of the Horsefly, BAT and Ellerslie.

The Horsefly is characterized by low values of Zr/Al_2O_3, but high values of K_2O/Al_2O_3 and Rb/Al_2O_3, whilst the BAT is clearly differentiated from both the Horsefly and Ellerslie by its low P_2O_5/Al_2O_3 and Rb/Al_2O_3 values. The Ellerslie has values that are intermediate between those of the Horsefly and the BAT and on simple Al_2O_3 normalized plots has no distinguishing features. In order to differentiate the Ellerslie elemental ratios need to be plotted, for example, the Ellerslie is clearly differentiated from the Horsefly and the BAT by its high values of K_2O/Rb (Fig 2).

Selected elements from all wells can also be plotted as binary and ternary diagrams in order to differentiate between the three units (Fig 3 and 4). Samples from the BAT and Ellerslie form two distinct positive linear relationships in Fig 3a, with samples from the Horsefly forming a less well-defined relationship. On Fig 3b-3d no clear linear relationships are apparent, but samples from each unit plot in well-defined fields. The ternary diagrams plotted in Fig 4 are constructed using three elemental ratios, which clearly differentiate the Ellerslie, BAT and Horsefly.

Mineralogy

Elemental variations in a whole rock sediment sample are controlled by changing mineralogy, making it important to relate the elemental composition to the mineralogy. By understanding the main influences on sediment mineralogy it is possible to comment on the geological controls responsible for the geochemical differentiation described above. Using mineralogical data (XRD and petrography) in association with element vs. element binary diagrams (Fig 5), it is possible to elucidate the main mineralogical controls on the geochemistry for each stratigraphic unit:

Clay minerals and feldspar: The concentrations of Al_2O_3, K_2O, Na_2O, Cr and Rb in the study intervals are controlled primarily by the clay mineralogy, with the BAT being relatively enriched in kaolinite and depleted in illite and illite/smectite. It also appears that the relatively minor feldspar amounts may be influencing concentrations of K_2O, with the Horsefly and Ellerslie having proportionally more feldspar than the BAT.

Heavy minerals: Of the key elements used in this study Zr, TiO_2 and Nb are potentially associated with heavy mineral concentrations. The BAT and Ellerslie are relatively enriched in Zr (therefore Zircon) concentrations, however this likely to be due to an increase in silt grade material within these units. TiO_2 and Nb are generally found in the same minerals and in this study have complex mineralogical affinities in the silty claystones of all three units, with influences of clay mineralogy, diagenetic anatase and detrital heavy minerals all controlling TiO_2 concentrations. Additionally, in the BAT, Nb concentrations indicate the presence of a mineral species that is preferentially enriched in Nb over TiO_2. Further mineralogical work is required to determine what this mineral species may be, however initial research suggests that this may be a distal expression of Nb rich volcanics on the Canadian Shield.

Carbonate and Iron Minerals: carbonate minerals are thought to be the primary control on CaO, MgO and Fe2O3 concentrations. However these elements display little or no systematic relationship to one another on binary diagrams, and are not used to differentiate between Horsefly, BAT and Ellerslie units.

Discussion

This paper demonstrates that chemostratigraphy can be used as an additional stratigraphic tool in the Lower Mannville Formation of the WCSB. The Horsefly, BAT and Ellerslie units can be readily differentiated geochemically from one another by considering the elemental compositions of the silty claystones. They key elements used for differentiation in this study are: Al_2O_3, Na_2O, K_2O, P_2O_5, Rb, Zr, Cr and Nb. Variations in concentrations of potassium (K), rubidium (Rb), sodium (Na) and aluminum (Al) are controlled by a mixture of changing clay mineralogy (climate) and feldspar content (provenance). Changes in concentrations of zirconium (Zr) and niobium (Nb) are controlled by variations in heavy mineralogy (provenance), and titanium (Ti) and chromium (Cr) are both controlled by a mixture of heavy mineral and clay mineral variations.

Once the elemental variations have been calibrated against cored intervals of known stratigraphy, it becomes possible to use the technique as a predictive tool. Therefore, if silty claystones from a core through the BQ of unknown stratigraphic affinities are collected and analyzed, plotting the geochemical data obtained on one of the ternary or binary diagrams displayed on Fig.'s 3 and 4 will allow it to be assigned to a stratigraphic unit.

More generally, the study demonstrates that chemostratigraphy is applicable in low accommodation fluvial settings, which stratigraphically are notoriously difficult to work with. By enabling regional correlation in low accommodation biostratigraphically barren sequences, chemostratigraphy has the potential to aid with regional mapping of reservoirs and thereby enhance confidence in reservoir management of mature basins.

References

Ardies, G.W., Dalrymple, R.W. and Zaitlin, B.A., 2002. Controls on the geometry of incised-valley systems in the Basal Quartz Unit (Lower Cretaceous), Western Canada Sedimentary Basin. Journal of Sedimentary Research,v. 72, No. 5, p.602-618.

Jarvis, I., and Jarvis, K., 1995, Plasma Spectrometry in earth sciences: techniques, applications and future trends. In: Jarvis, I., Jarvis, K.E. (Eds) Plasma Spectrometry in Earth Sciences. Chem. Geol 95. 1-33.

Pearce, T.P., Besly, B.M., Wray, D.S. and Wright, D.K., 1999. Chemostratigraphy: a method to improve interwell correlation in barren sequences - a case study using onshore Duckmantian/Stephanian sequences (West Midlands, U.K.) Sed. Geol. 124, 197-220.

Zaitlin, B.A., Potocki, D., Warren, M.J., Rosenthal, L., and Boyd, R., 2002. Depositional styles in a low accommodation foreland basin setting: an example from the Basal Quartz (Lower Cretaceous), southern Alberta. Bulletin of Canadian Petroleum Geology, V. 50, No 1, p.31-72.

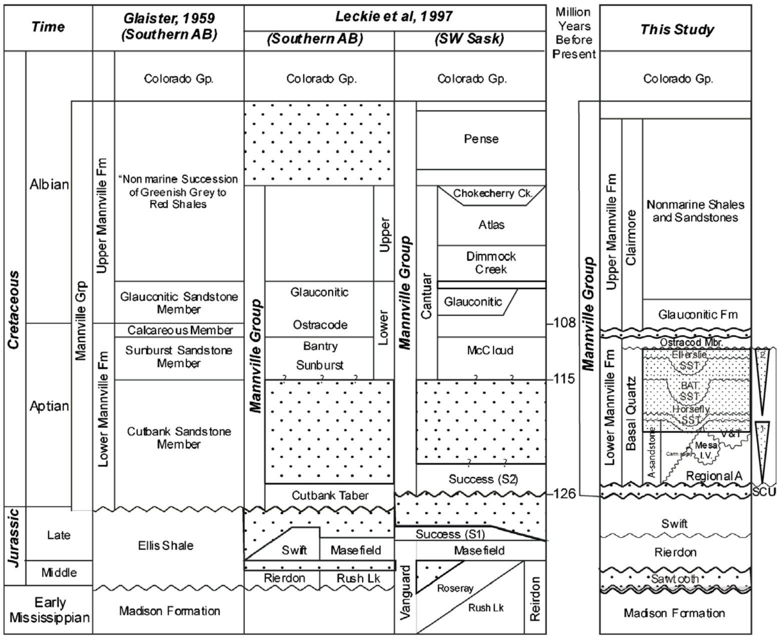

Figure 1:Location map showing location of study area in North America with a detailed map of the study area in Alberta on which isopach grades for the Lower Mannville are displayed.

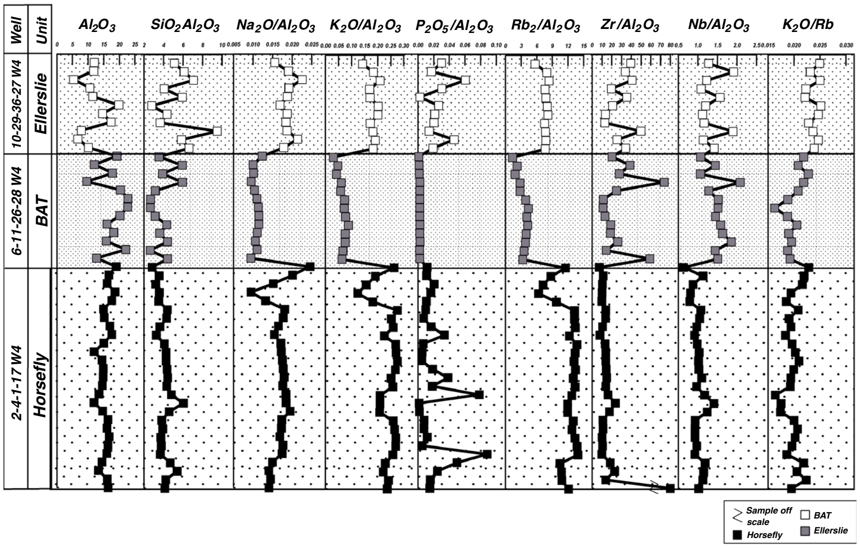

Figure 2:"Synthetic" geochemical profiles constructed for samples from the Horsefly (well 2-4-1-17 W4), the BAT (Well 6-11-26-28 W4) and the Ellerslie (Well 10-29-36-27 W4). The profiles are constructed to visually display geochemical differences between the units such that each sample is in the correct stratigraphic order, but there is no inference of its absolute depth (see text for discussion). Each square represents an analyzed sample.

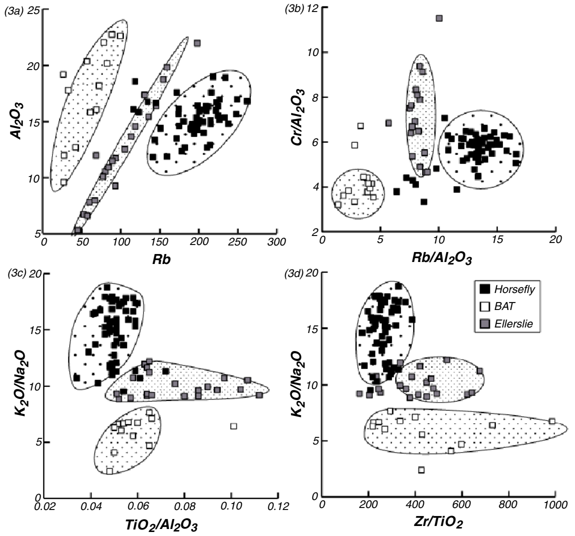

Figure 3:Binary diagrams constructed for selected element ratios. Each square represents an analyzed sample and all analyzed samples, are depicted on the graphs. The ratio's used have been selected to maximize the geochemical characterization, such that samples from each of the stratigraphic units (Horsefly, BAT and Ellerslie), form well-defined separate linear trends or groups.

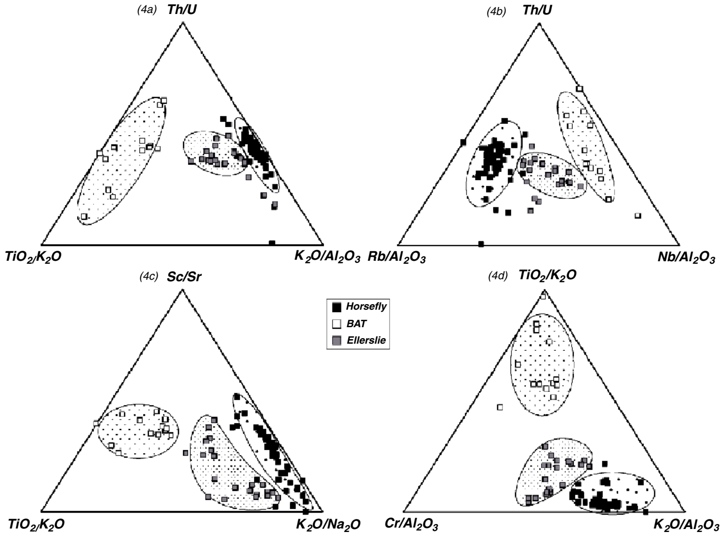

Figure 4:Ternary diagrams constructed for selected element ratios. Each square represents an analyzed sample and all analyzed samples are depicted on the graphs. The ratio's used have been selected to maximize the geochemical characterization, such that samples from each of the stratigraphic units (Horsefly, BAT and Ellerslie), form well-defined groups.

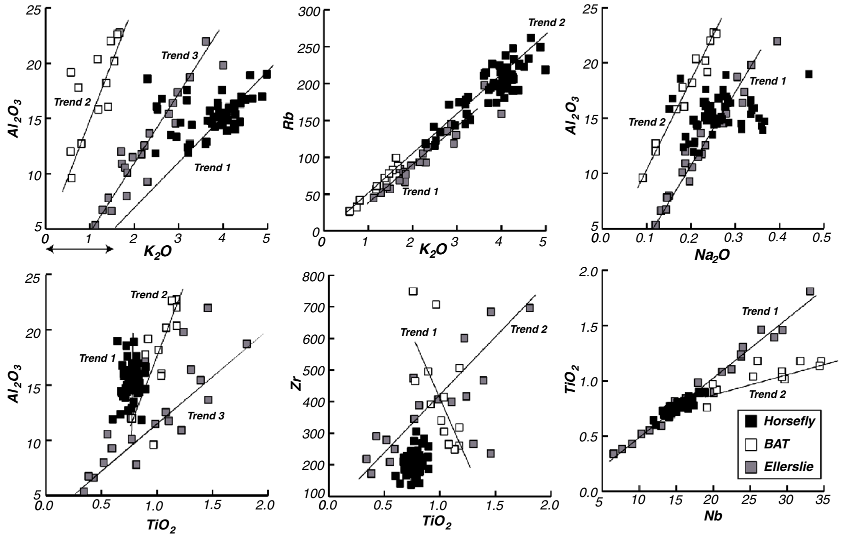

Figure 5:Binary diagrams constructed to display co-linear relationships between selected elements. These types of diagrams can be used to make inferences about element-to-element relationships and therefore element to mineral relationships.