# Middle Carbonate Member in Black Shale – a view from core, thin sections, and logs – the Duvernay versus black shale analogues

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## Summary

The present paper attempts to assess a plausible genetic and tectonic link between the presence of a carbonate middle-member within black organic shale and major transgressions. Whereas the focus is the Duvernay shale, Devonian in age, observations are also drawn from other shales such as the Montney, Exshaw, Bakken, Marcellus and Eagle Ford.

The important distinction between carbonate cement and depositional limestone is addressed via core observations, thin sections petrography and, XRD and XRF characteristics. We reviewed the carbonate mid-member by using log facies maps (Figure 1) and continuous XRF to complement core descriptions (e.g. Figure 2). Geometrical analysis of relative bed thicknesses has been done using Bischke plots, also called Delta D/D plots (Tearpock and Bischke, 2003); such plots help understand some of the reasons for bed thickness variations (Figure 3). In order to achieve a reliable interpretation, a Bischke Plot is prepared using a dataset consisting of many well tops (of upper and lower shale and carbonate units - see Figure 3). As a complement, high resolution vertical profiling of 256 shades of grey-colour has been used as a first pass to discriminate between carbonate types as well as to define accommodation space and carbonate factory supply. Shale and carbonate/siliciclastic base-lines, created using gamma ray logs (Figure 1) can help determine the 3rd and 4th order sedimentary cycles.

In some unconventional reservoirs, such as the Montney silty hybrid mudstone, the Ca vs Mn cross-plots of XRF elemental composition has provided a basis to easily distinguish between true (depositional as opposed to diagenetic) limestone beds and carbonate cements. However, the best elements and the most useful ratios for other shale formations have yet to be defined.

To address basin fluctuations, anoxicity changes and accommodation space through time, gamma ray shale base lines have been defined for each well and compared to clastic/carbonate influx baselines (much more interpretative). Thus, the interpreted gamma ray shale baseline clearly indicates an overall increase in anoxicity from lower to upper Duvernay Shale sandwiching/encasing the middle carbonate member (Figure 1). The mechanism linked to the existence of the carbonate middle member has yet to be investigated in detail; however, some core observations clearly show the presence of downslope transported elements (e.g. Duvernay debrites and Montney tempestites) which need to be placed into a regional context.

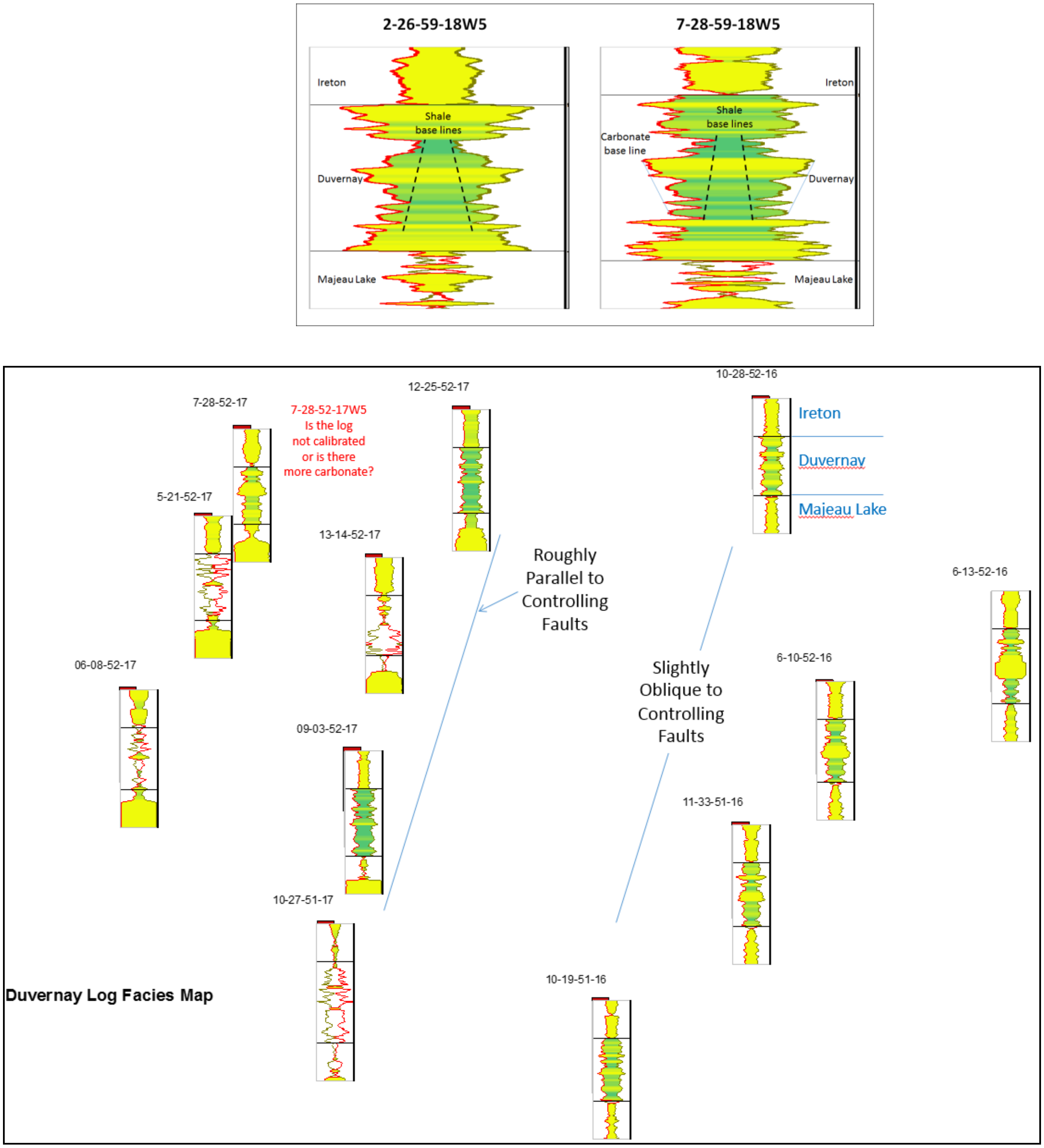
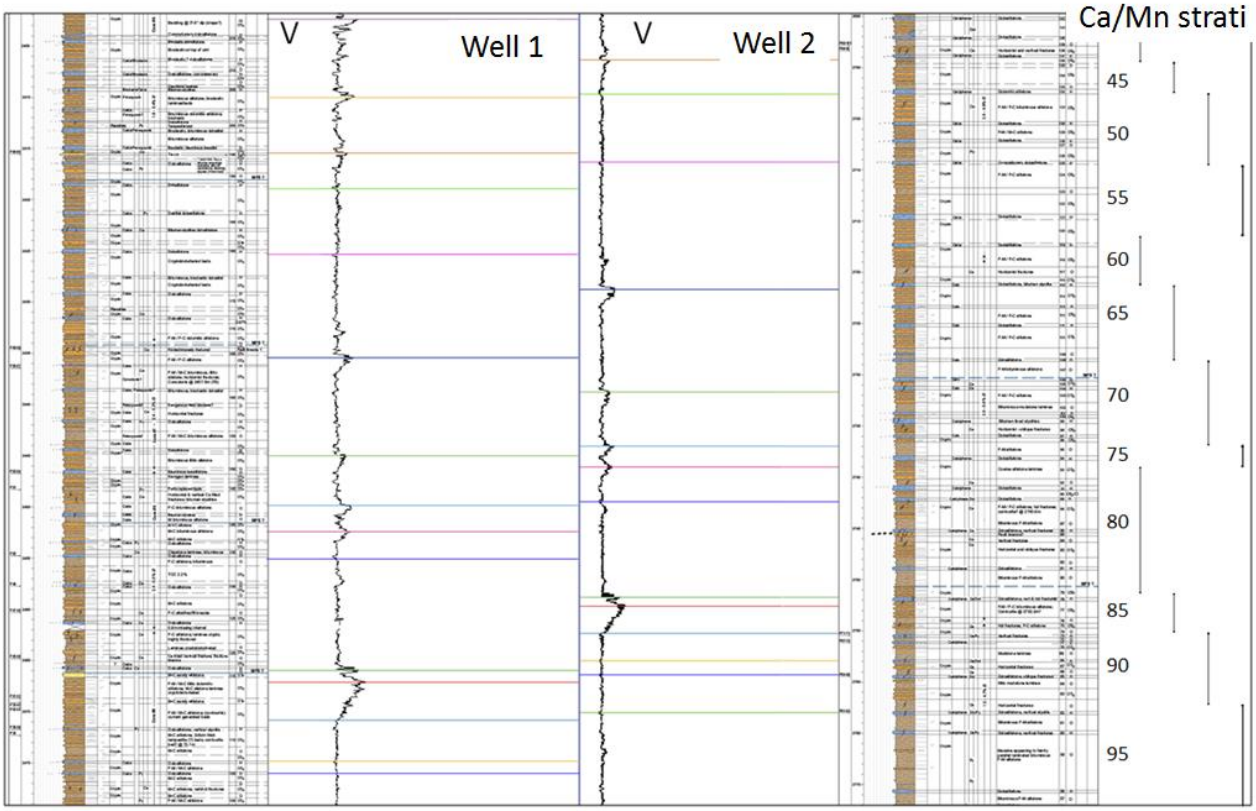



Fig.1: Variable expression of the Duvernay Middle Carbonate Member (yellow) in logs and log facies map.

The selected detailed profiles of the two selected wells in Figure 1 clearly indicate that the whole of the Duvernay corresponds to a sedimentary package deposited in response to a single transgression; the middle carbonate member obliterates this simple trend.

A high degree of similarity is recognized between pairs of wells using log profiles (GR and reverse GR – color fill based on un-normalized gamma ray). The best log similarity falls parallel to a known structural grain direction oriented North 10 degrees, ubiquitous in the WCSB (Chatellier et al. 2010).

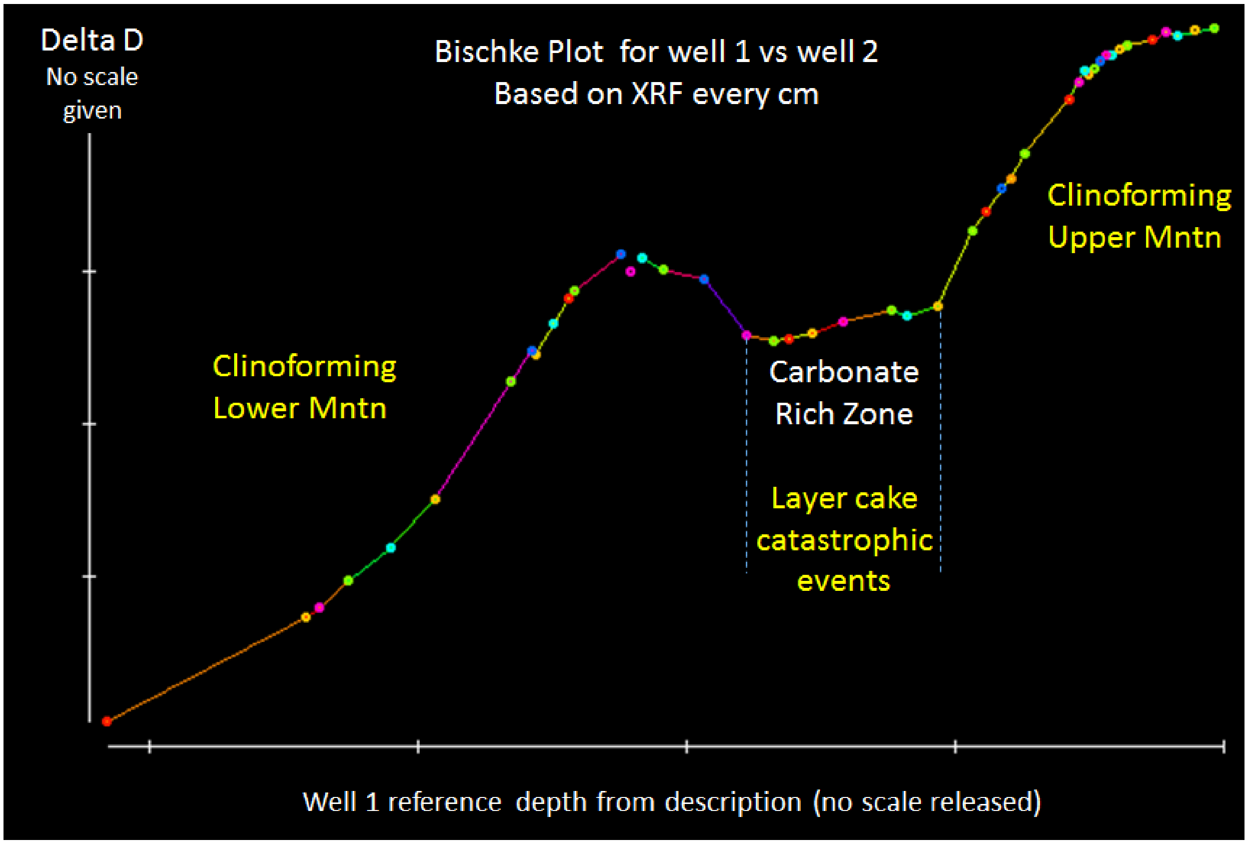
Correlation markers using Vanadium, Zirconium and Manganese XRF profiles




After Chatellier et al. 2015

Fig.2: Core description and correlation of the mid carbonate member within the Montney Formation based on XRF elemental composition

The lithologies of the blue beds in the c-65-F/ 94-B-8 (left) and c-6-L/94-B-8 (right) are carbonate facies of either dolosiltstone or bioclastic packstone to wackestone. Continuous XRF delivers a reliable and detailed correlation framework based on elemental composition with an outstanding match between wells some 7km apart. Each stratigraphic unit based on Ca/Mn is 5 to 15 meter thick; the top of each unit has been used in the construction of the Bischke Plot shown on Figure 3.The only XRF element profile shown in the figure is that of Vanadium, which is outstanding as a proxy for anoxicity and TOC. The right end box shows the stratigraphical scheme extracted from the Ca/Mn trend analysis. The figure shows some 80 meters of core in both of the wells.




See previous plot for XRF vs core description

Fig.3: Geometric analysis of thickness changes using the Multiple Plot Bischke Plot Analysis.

In the plot, each dot corresponds to a chemotratigraphic top as defined by continuous XRF analysis (see Fig.2) ; there is no particular meaning to the applied color scheme.The changes in thickness in the Upper and Lower Montney are proportional between the two wells and are indicative of prograding patterns in these two silty packages. The middle member of the Montney is made up of numerous carbonate beds intebedded with silty beds; the thicknesses are roughly constant between the two wells in great contrast with the other two members.The observed reverse trend indicates that the more proximal well has been the subject of more erosion than the more distal well. This erosional time event is a precursor to the tectonically derived tempestites, characterized by carbonate bioclasts and easily identified on XRF by Ca vs Mn plots.

References

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