Building a Sequence Stratigraphic Framework using Chemostratigraphy: An Example from the Devonian Canol Formation, Northwest Territories

Maya T. LaGrange[1], Brette S. Harris[1], Murray K. Gingras[1]
[1]University of Alberta

Summary

Sequence stratigraphy is useful for understanding basin history and to facilitate regional correlation of reservoir intervals in sedimentary successions (Catuneanu *et al.,* 2009). However, establishing a stratigraphic framework for mudstone intervals can be challenging because often the datasets traditionally used in coarser grained successions (e.g. geophysical, biostratigraphic, petrophysical, or sedimentological datasets) are unavailable or of limited use (Ratcliffe *et al.,* 2012; Pearce *et al.,* 2005). As a result, many studies are incorporating chemostratigraphy when studying fine-grained successions, meaning that whole-rock geochemistry is used for characterization and correlation of stratigraphic units (Ratcliffe *et al.,* 2010; Pearce *et al.,* 1999). Furthermore, chemostratigraphic proxies are being employed to interpret sequence stratigraphic cycles (e.g. Turner *et al.,* 2016; Sano *et al.,* 2013). This project presents data from the Middle to Late Devonian Canol Formation, an organic-rich mudstone present in the Northwest Territories, to demonstrate how elemental proxies can be used to establish a sequence stratigraphic framework.

Methods

The Middle to Late Devonian Canol Formation is present in the Central Mackenzie Valley and Mackenzie Mountains of the Northwest Territories, Canada. It is the known source rock for the hydrocarbons produced from the Kee Scarp reefs at Norman Wells (Snowdon *et al*., 1987) and is currently an unconventional reservoir prospect. Elemental composition data has been collected for the Canol Formation using a hand-held x-ray fluorescence analyzer from four Central Mackenzie Valley cores and one outcrop in the Mackenzie Mountains. Data was collected every 10 cm for cores and every 50 cm for the outcrop.

Chemostratigraphy has been successfully used in many studies of mudstone successions (e.g. Playter *et al.,* 2017; El Attar & Pranter, 2016; Ratcliffe *et al.,* 2012). However, there are certain limitations to using chemostratigraphic profiles including the potential for elements to migrate as a result of post-depositional re-oxidation, diagenesis, or weathering (Tribovillard *et al.,* 2006; Pearce *et al.,* 2006). As a result, multiple elemental proxies for the same environmental condition are typically considered.

Trends in elements primarily associated with detrital sediment (e.g. Al, K, Ti, Zr) can be used to infer abundance of terrigenous input (Chen *et al.,* 2013). Proxies such as Si trends compared Zr trends, and Si-Al or Si-Zr cross plots can provide information about proportion of biogenic sediment (Turner *et al.,* 2015; Tribovillard *et al.,* 2006) and redox sensitive trace metals (e.g. Ni, Mo, V) can be used to interpret dissolved oxygen at the time of deposition (Tribovillard *et al.,* 2006). Together, these elemental profiles can be used to infer paleoshoreline trajectories, sequence stratigraphic surfaces, and systems tracts. In this study, regression is interpreted based on decreasing abundance of terrigenous input reflected by declining Al, Ti, and Zr, lower biogenic sediment abundance interpreted by trends in Si that follow trends in Zr, and increased dissolved oxygen resulting in lower enrichment of Mo and V. Opposite trends in these proxies were interpreted to be the product of transgression. Maximum flooding surfaces are interpreted at the transition from transgression to regression while maximum regressive surfaces are placed at the boundary between regression and transgression. Figure 1 gives an example of the geochemical expression of transgression, regression, maximum flooding surfaces and maximum regressive surfaces in the Canol Formation. The identification of these surfaces and systems tracts can allow for recognition of Transgressive-Regressive sequences with maximum regressive surfaces as sequence boundaries following Embry (2002).

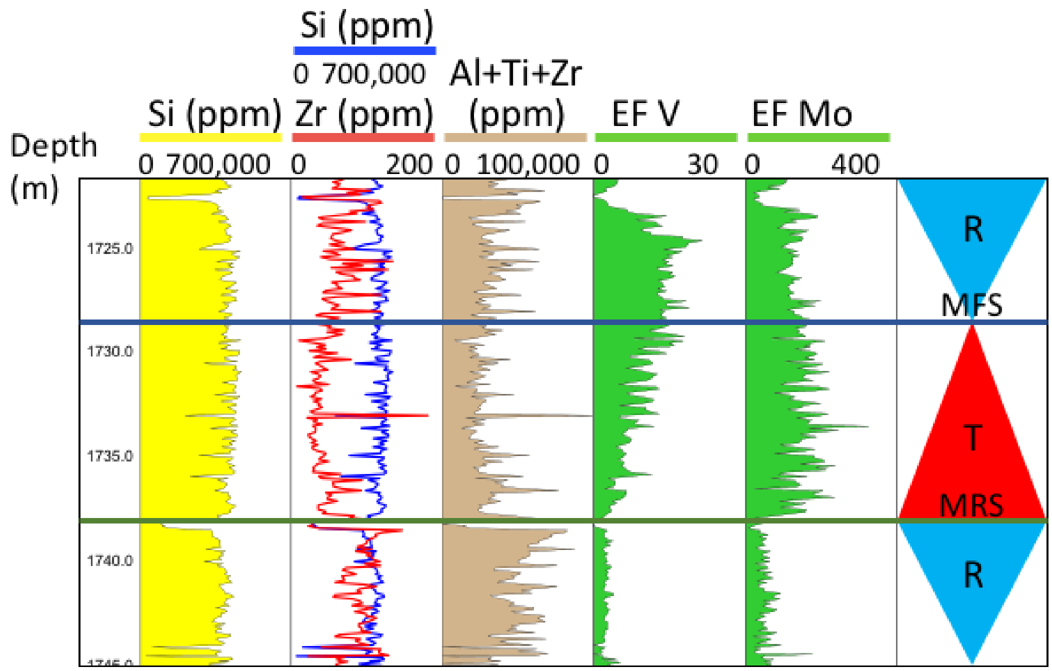

Figure 1. The chemostratigraphic expression of transgression (T), regression (R), maximum flooding surfaces (MFS), and maximum regressive surfaces (MRS) in the Canol Formation. Vanadium enrichment (EF V) and molybdenum enrichment (EF Mo) are relative to the Post-Archean Average Australian Shale of Taylor and McLennan (1985).

Results

Preliminary results show that it is possible to identify Transgressive-Regressive sequences in the Canol Formation using a chemostratigraphic dataset. Furthermore, these sequences can be correlated between cores in the Central Mackenzie Valley and an outcrop in the Mackenzie Mountains. Future work for this project will involve integrating sedimentological and ichnological observations to strengthen sequence stratigraphic interpretations and incorporating data from four additional outcrops in the Mackenzie Mountains.

Conclusions

A chemostratigraphic dataset from the Canol Formation in the Central Mackenzie Valley and Mackenzie Mountains of the Northwest Territories demonstrates that elemental proxies can be used to build a sequence stratigraphic framework in mudstone successions. This facilitates mapping of heterogeneities in organic-rich mudstone successions, which is valuable to the exploration and development of unconventional shale plays.

Acknowledgements

The authors would like to thank the Northwest Territories Geological Survey for financial support of this project and Advanced Logic Technology for providing access to WellCAD.

References

Catuneanu, O., Abreu, V., Bhattacharya, J.P., Blum, M.D., Dalrymple, R.W., Eriksson, P.G., Fielding, C.R., Fisher, W.L., Galloway, W.E., Gibling, M.R., Giles, K.A., Holbrook, J.M., Jordan, R., Kendall, C.G.St.C., Macurda, B., Martinsen, O.J., Miall, A.D., Neal, J.E., Nummedal, D., Pomar, L., Posamentier, H.W., Pratt, B.R., Sarg, J.F., Shanley, K.W., Steel, R.J., Strasser, A., Tucker, M.E., Winker, C., 2009. Towards the standardization of sequence stratigraphy. Earth Science Reviews. 92, 1–33.

Chen, H. F., Yeh, P. Y., Song, S. R., Hsu, S. C., Yang, T. N., Wang, Y., Zhenqing, C., Lee, T.Q., Chen, M.T., Cheng, C.L., Zou, J., Chang, Y.P., 2013. The Ti/Al molar ratio as a new proxy for tracing sediment transportation processes and its application in aeolian events and sea level change in East Asia. Journal of Asian Earth Sciences. 73, 31-38.

Embry, A. F., 2002. Transgressive-regressive (TR) sequence stratigraphy. In Gulf Coast SEPM Conference Proceedings, Houston, pp. 151-172.

El Attar, A., Pranter, M. J., 2016. Regional stratigraphy, elemental chemostratigraphy, and organic richness of the Niobrara Member of the Mancos Shale, Piceance Basin, Colorado. AAPG Bulletin. 100, 345-377.

Pearce, T.J., Wray, D., Ratcliffe, K., Wright, D.K., Moscariello, A., 2005. Chemostratigraphy of the Upper Carboniferous Schooner Formation, southern North Sea.

Playter, T., Corlett, H., Konhauser, K., Robbins, L., Rohais, S., Crombez, V., Maccormack, K., Rokosh, D., Prenoslo, D., Furlong, C., Pawlowicz, J., Gingras, M., Lalonde, S., Lyster, S., Zonneveld, J., 2018. Clinoform identification and correlation in fine-grained sediments: A case study using the Triassic Montney Formation. Sedimentology. 65, 263-302.

Ratcliffe, K. T., Wright, A. M., Schmidt, K., 2012. Application of inorganic whole-rock geochemistry to shale resource plays: an example from the Eagle Ford Shale Formation, Texas. The Sedimentary Record. 10, 4-9.

Jennifer L. Sano, Ken T. Ratcliffe, and D.R. Spain, 2013, Chemostratigraphy of the Haynesville Shale. In: Hammes U., Gale J., (Eds.), Geology of the Haynesville Gas Shale in East Texas and West Louisiana, U.S.A. AAPG Memoir 105, pp. 137–154.

Snowdon, L.R., Brooks, P.W., Williams, G.K., Goodarzi, F., 1987. Correlation of the Canol Formation source rock with oil from Norman Wells. Organic Geochemistry. 11, 529-548.

Taylor, S.R., McLennan, S.M., 1985. The Continental Crust: Its Composition and Evolution. Blackwell, Malden, Mass.

Tribovillard, N., Algeo, T. J., Lyons, T., Riboulleau, A. 2006. Trace metals as paleoredox and paleoproductivity proxies: an update. Chemical geology. 232, 12-32.

Turner, B. W., Molinares-Blanco, C. E., Slatt, R. M., 2015. Chemostratigraphic, palynostratigraphic, and sequence stratigraphic analysis of the Woodford Shale, Wyche Farm Quarry, Pontotoc County, Oklahoma. Interpretation. 3, SH1-SH9.

Turner, B. W., Tréanton, J. A., Slatt, R. M., 2016. The use of chemostratigraphy to refine ambiguous sequence stratigraphic correlations in marine mudrocks. An example from the Woodford Shale, Oklahoma, USA. Journal of the Geological Society. 173, 854-868.