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Assessing Event Sedimentation in the Bluesky Formation of the Peace River Oil Sands using the Ichnogenus *Rosselia*

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Summary

Spectacular examples of well-preserved, stacked *Rosselia* Dahmer, 1937 have been observed in Cretaceous Bluesky Formation core from Alberta's Peace River oil sands deposit. Stacked *Rosselia* segments reflect burrow re-adjustments of a single tracemaker following sedimentation. These traces can be used as a 'measuring stick' for determining the magnitude and frequency of sedimentation events (MacEachern and Pemberton 1992; Nara, 1995, 1997). In this study, two cores with *Rosselia* were logged, sedimentological and ichnological characteristics were scrutinized and the length and number of stacked segments were measured. These cores are interpreted to represent shoreface deposition in a wave-influenced bay. *Rosselia* burrows record one to two post-depositional re-establishments per tracemaker, where each re-adjustment represents an average 3.6 cm to 5.6 cm of sediment deposition. In extreme cases, up to four re-adjustments totaling nearly 30 cm were observed, reflecting multiple depositional events in a relatively short time frame--months to perhaps two years depending on the lifespan/growth rate of the organism (Seitz and Schaffner, 1995). The use of *Rosselia* in this study provides high-resolution analysis of modal sedimentation in the Bluesky Formation, a depositional parameter rarely measurable in the rock record but fundamental to understanding sedimentary processes.

Introduction

The early Cretaceous Bluesky Formation within the Peace River oil sands deposit of west-central Alberta, Canada hosts significant subsurface bitumen reserves (Attanasi and Meyer, 2010; Energy Resources Conservation Board, 2013). Sedimentological, ichnological and stratigraphical techniques have been used in past studies to discern the depositional environments and events influencing all aspects of sedimentation, reservoir quality, reservoir heterogeneity and areal extent of the Bluesky Formation. Broadly speaking, Bluesky Formation sands and muds have been attributed to deposition in the shoreface, in wave-dominated estuaries and in tide-dominated estuaries and deltas (Jackson, 1984; Male, 1992; Brekke, 1995; Hubbard et al. 1999, 2002; Mackay and Dalrymple, 2005, 2008, 2011). Missing from past research is an understanding of modal sedimentation in the Bluesky. Depositional rates and volumes are fundamentally important to process sedimentology, however, assessing these parameters in the rock record is extremely difficult (Dott 1983; Nara 1995; 1997).

The occurrence of the ichnogenus *Rosselia* Dahmer, 1937 in core provides a unique opportunity to measure these depositional aspects and conduct fine-scale paleoenvironmental analyses (Nara, 1997). *Rosselia* is a spindle to funnel shaped mud-lined tube interpreted to be the feeding and sediment-stowage burrow of a terebellid polychaete. Stacked *Rosselia* segments are considered to be re-equilibration adjustment structures of a single tracemaker maintaining its connection to the sediment-water interface following high sedimentation. The length and number of stacked re-adjustments can be measured and used as a proxy for assessing the magnitude and frequency of depositional events (MacEachern and Pemberton 1992; Nara, 1995, 1997).

Theory and/or Method

The research area encompasses Townships 81-84 and Ranges 14W5-18W5, an area of extensive bitumen exploration and production. A number of wells penetrating the Bluesky have been studied and recovered core was logged. Two cores containing assemblages of robust, stacked *Rosselia* were selected for further scrutiny. Sedimentological constituents analyzed included grain-size, lithological constituents, bed contacts and bed thickness, primary physical sedimentary structures and penecontemporaneous structures. Ichnological observations included identification of ichnogenera, their relative abundance, ichnofossil size and bioturbation intensity. AppleCore© software was used to record these observations. Tentative facies and facies associations were erected and depositional environment interpretation followed.

In order to shed light on modal sedimentation in the Bluesky Formation, the length and number of stacked segments were measured and counted in the core where *Rosselia* occurred. An uninterrupted continuous stack of *Rosselia* segments represents the upward burrowing of one organism over its sedimentologically preserved life, and each segment along the stack reflects one re-adjustment following a depositional event. The height of each segment corresponds to the vertical distance the burrower climbed to re-equilibrate; therefore, it was possible to determine the amount of sediment deposited by measuring the length of each segment. The frequency of depositional events in any one lifetime was determined by counting the number of segments in a stack (also see Nara 1995; 1997).

Examples

Core example #1 is from well 8-12-83-18W5 and core example #2 is from well 5-13-82-18W5. Strip logs and box shot are presented in Figure 1 for core #1 and in Figure 2 for core #2 (See Appendix 1 for a strip log symbols legend.). Physical sedimentary structures and ichnofacies consistent with a wave-influenced bay shoreface were noted. Sedimentary features include wavy parallel lamination, low angle planar tabular lamination and micro-hummocky cross stratification. *Cruziana* and *Skolithos* ichnofacies elements were also observed and include assemblages of *Rosselia*, *Macaronichnus*, *Asterosoma*, *Cylindrichnus*, *Planolites*, *Diplocraterion*, *Thalassinoides* and *Teichichnus* (MacEachern and Pemberton, 1992).

Figure 1: Core example #1 from well 8-12-83-18W5. *Rosselia* contained within the yellow boxes were subjected to further scrutiny in order to understand sedimentation magnitudes and frequency. Sedimentary features and ichnofossils appear in the strip log. Low angle planar tabular lamination, wavy parallel lamination and micro-hummocky cross stratification are noted. Ichnofacies consistent with the shoreface are present. Scale bar on core is 5 cm. Symbols legend appears in Appendix 1.

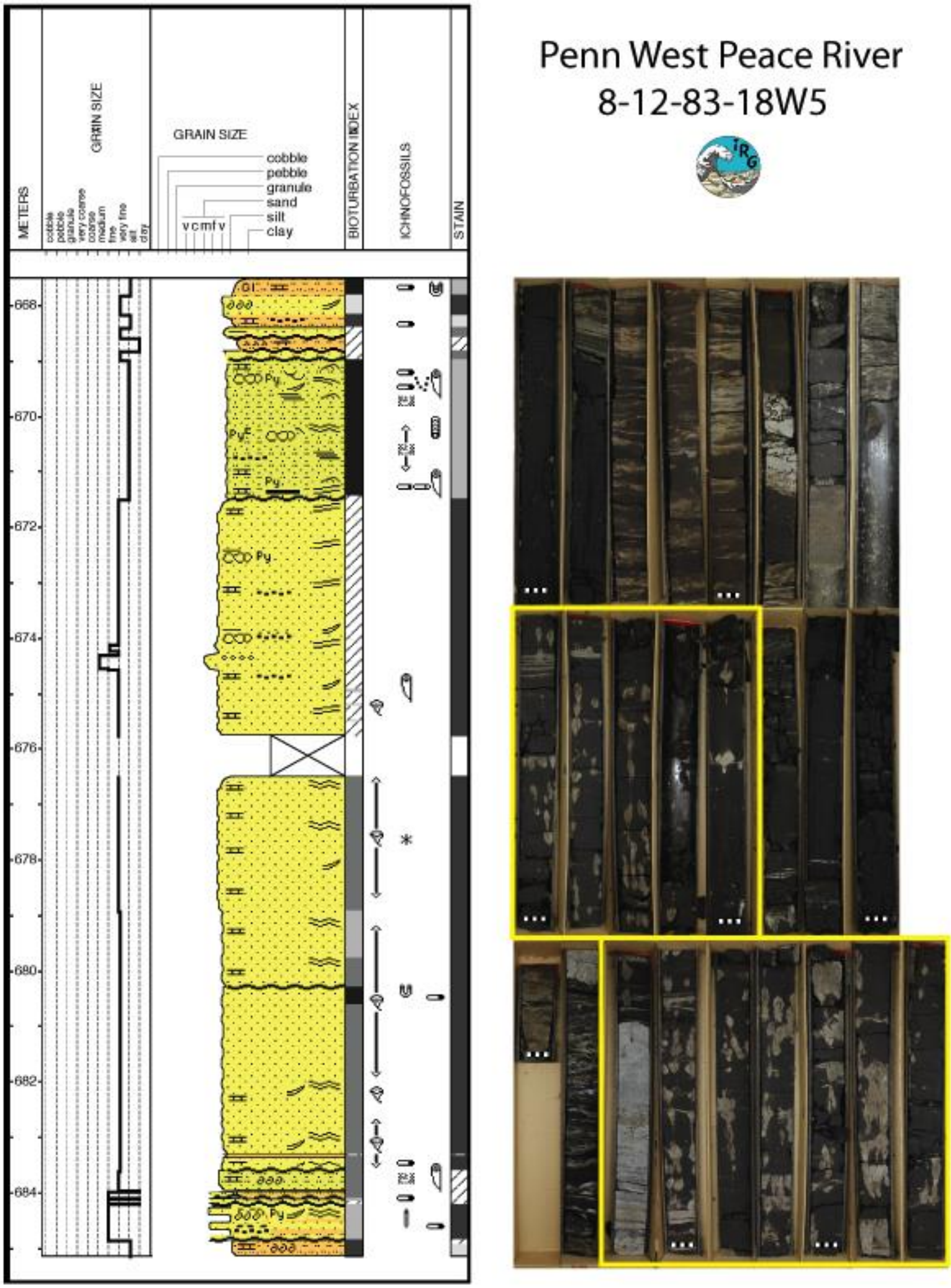


Figure 2: Core example #2 from well 5-13-82-18W5. *Rosselia* contained within the yellow boxes were subjected to further scrutiny in order to understand sedimentation magnitudes and frequency. Sedimentary features and ichnofossils appear in the strip log. Low angle planar tabular lamination and wavy parallel lamination are noted. Ichnofacies consistent with the shoreface are present. Scale bar on core is 5 cm. Symbols legend appears in Appendix 1.

Figure 3 shows the measured re-adjustments of *Rosselia* in core #1 and Figure 4 shows the measured re-adjustments in core # 2. In response to sedimentation, the average tracemaker re-equilibration response in core #1 is 3.6 cm and 5.6 cm in core #2. This re-positioning suggests that the amount of event deposition averaged 3.6 cm and 5.6 cm, respectively. Extreme adjustments were observed when the cumulative effect of an organism's movements was considered, *i.e*., a single tracemaker may have been subjected to almost 30 cm of sediment deposition over four separate events in the course of its lifetime. Given that all segmented burrows of a stacked *Rosselia* occur in the biological lifespan--months to perhaps two years--of a single tracemaker, the Bluesky *Rosselia* assemblage in the study area records significant sediment deposition in a relatively short time period (Seitz and Schaffner, 1995).

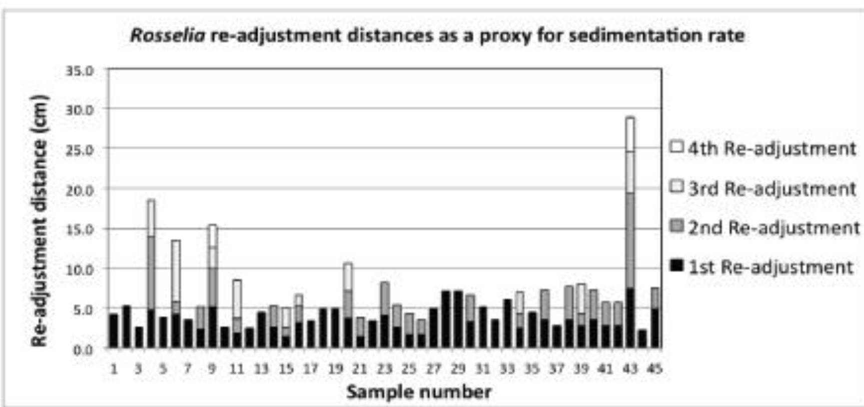
Conclusions

Depositional rates and volumes are fundamentally important to process sedimentology, however, assessing these parameters in the rock record is extremely difficult (Dott 1983; Nara 1995; 1997). The presence of stacked *Rosselia* in these two cores provides a unique opportunity to study depositional events and environments in the Bluesky Formation. The *Rosselia* were found within wave-dominated shoreface deposits. The presence of micro-hummocky cross stratification, erosionally truncated burrows as well as rapid and significant levels of sedimentation indicate storm influences in a rapidly prograding bay margin during Bluesky deposition (MacEachern and Pemberton, 1992; Nara, 1997). The magnitude and frequency of these sedimentation events were reflected in the re-adjustment burrows of the tracemaker. Large volumes of sand were deposited in the shoreface in a relatively quick period of time. This study highlights the use of *Rosselia* as a precision tool for fine-timescale analyses in the rock record.

Acknowledgements

This study was made possible through the generous support of Murphy Oil Corporation Ltd. and a matching collaborative research grant by the Natural Sciences and Engineering Research Council of Canada.

Figure 3: *Rosselia* studied in core 8-12-83-18W5. Individual stacks of *Rosselia* segments were identified and numbered (1-45). Re-adjustments were counted (a-d) and lengths were measured. Note erosional truncations (pink arrows). Results are graphically presented. One to two re-adjustments (segments) per tracemaker are observed, but greater re-positionings do occur (specimen #43). The average re-equilibration is 3.6 cm. Scale bar on core is 5 cm.



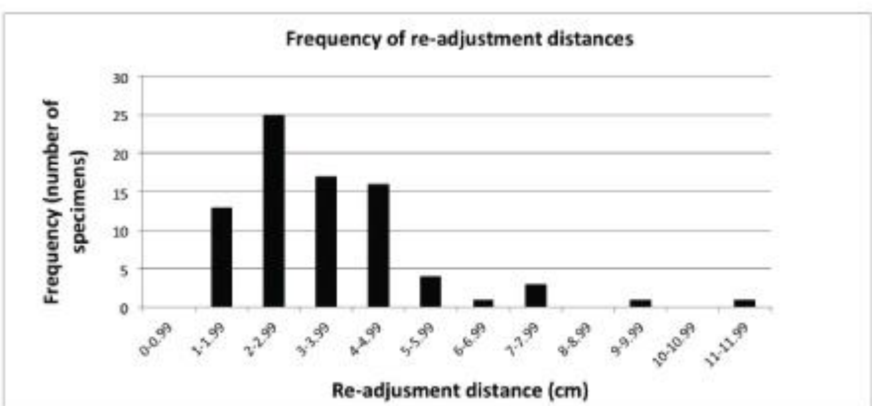
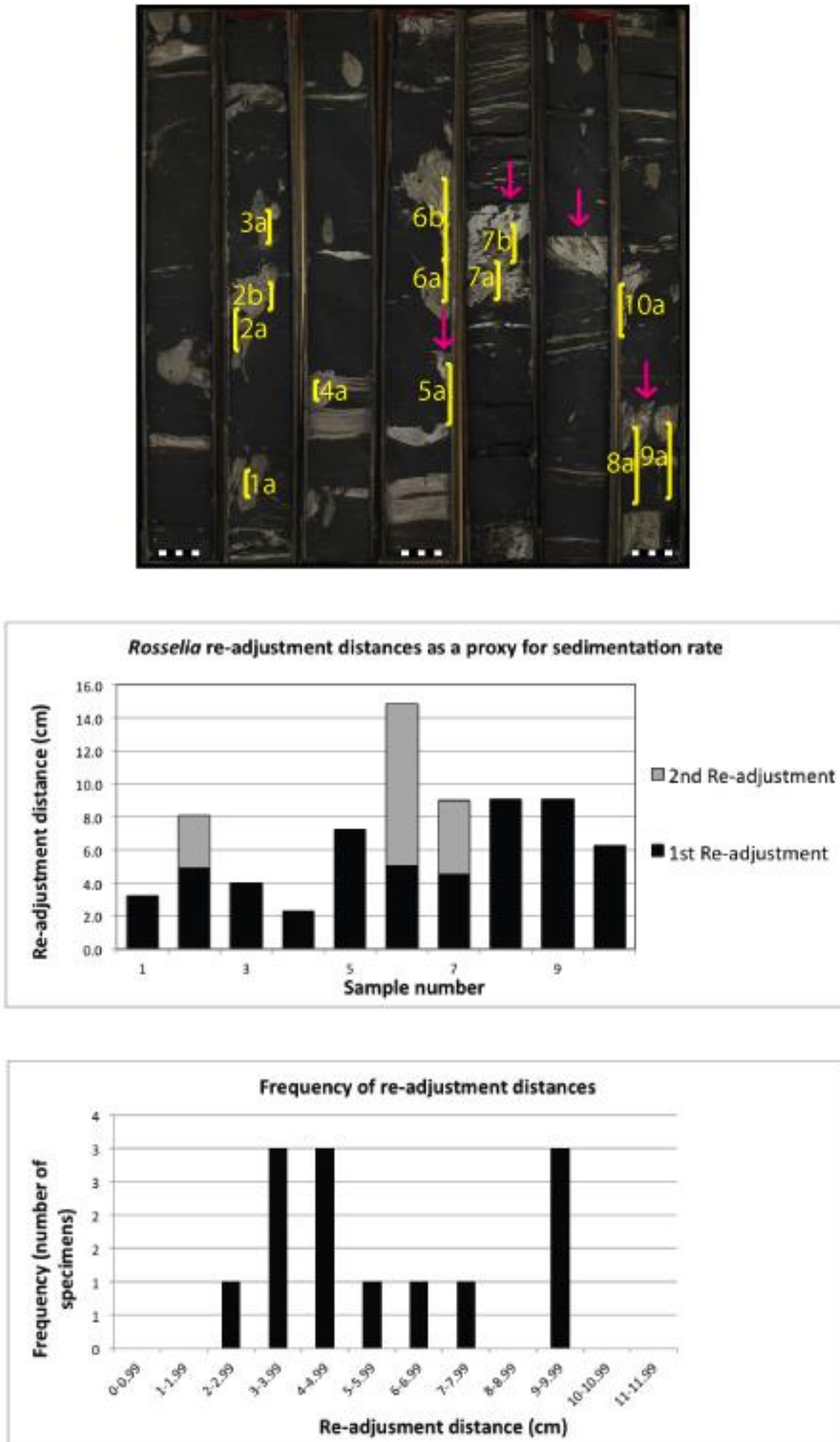


Figure 4: *Rosselia* studied in core 5-13-82-18W5. Individual stacks of *Rosselia* segments were identified and numbered (1-10). Re-adjustments were counted (a-b) and lengths were measured. Note erosional truncations (pink arrows). Results are graphically presented. One to two re-adjustments (segments) per tracemaker are observed. The average re-equilibration is 5.6 cm. Scale bar on core is 5 cm.



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Appendix 1: Symbols legend for core strip logs.