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The Moberly Member (Waterways Formation) Outcrops in the Athabasca Oil Sands Region: A new look at a classic correlation

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Summary

We present an updated correlation and composite section of the Moberly Member (Waterways Formation) outcrops in the Athabasca Oil Sands mining region in Alberta. Notable trends in the lithology and paleontology of the outcrops include (a) a southward increase in the argillaceous portion of the sediment in the lower part of the section and a northward increase in argillaceous sedimentation in the upper portion of the section; (b) a general decline in fossil abundance and richness diversity in the upper portion of the section, along with the disappearance of some fossil taxa; (c) a northeast-southwest trend in the Moberly Member biostrome unit from one dominated by branching, bulbous, and tabular forms in the northeast to one with only massive stromatoporoids surrounded by *Radiatrypa* brachiopods in the south to a presumably offshore, non-biostromal unit containing a diverse fauna and heavily bioturbated with *Thalassinoides* burrow networks in the southwest.

Introduction

The Moberly Member (Waterways Formation) outcrops along the Athabasca River have caught the attention of early explorers through recent geologists, in its relationship to the overlying McMurray Formation oil sands, as a potential resource for lime, as a structural enigma, and as a Devonian unit rich in fossils. Previous work on the Moberly Member outcrops is fairly extensive and well done, but herein we present an updated correlation and composite section for the Moberly Member outcrops in the Athabasca oil sands region, including notes on a few observed lithological and paleontological trends.

Fieldwork

From 2010 through 2012, we described Devonian carbonate outcrops in the Athabasca oil sands region. Key beds, such as biostromal or stromatoporoid-bearing units, allowed easy correlation of Moberly Member outcrops along the Athabasca River and in nearby areas. From these descriptions, we reconstructed a composite section of 15 distinct units for the region (Figure 1), which captures the general lithological and paleontological trends for the Moberly Member outcrops in the region.

Composite section

Most outcrops could be correlated, and thus contribute to the composite section. Only a few outcrops along the Muskeg River could not be correlated because of similarity to several units in the composite section.

The composite section for the Moberly Member emphasizes the dominance of argillaceous, nodular to wavy bedded limestone in the section. Resistant beds tend to be less argillaceous and more

fossiliferous, but comprise less than 25% of the section. Shale is rare, and occurs only in thin beds or as interbeds between wavy beds or limestone nodules.

The composite section extends almost to the base of the Moberly Member, based on comparisons to core. Outcrops along the Christina and Clearwater rivers contain the deepest portion of the section. The highest beds are present along the Athabasca River and in outcrops along some of the tributary rivers in the northern portion of the study area. Unit 6 and portions of the overlying and underlying beds are most common among the described outcrops. Thus, the middle of the composite section is best represented in the outcrops visited during the study.

Trends in Lithology and Paleontology

In general, stratigraphic (vertical) trends can be split between those above and below Unit 6. Regional (spatial) trends through the study area tend to fall along a northeast-southwest gradient, but often suggest a greater degree of complexity than a simple linear gradient.

An increase in the argillaceous portion of the lithology.

During the deposition of the Waterways Formation, the influx of terrigenous mud was from the present-day north and northeast. Although this regional trend is well documented in subsurface data, patterns within the outcrop data in this more localized study area do not always follow the regional trend.

Below Unit 6, the argillaceous content in the limestone increases southward, rather than northward. In the north, the units below Unit 6 form cliffs of very consistent, tabular to wavy, fossiliferous floatstone, but to the southwest, these units become more argillaceous and highly variable in lithology and fossil content.

Above Unit 6, the limestone becomes more argillaceous to the north. In the southern portion of the study area, most of the section forms a moderately recessive succession of tabular to wavy limestone beds interrupted by resistant units. Northward, these same beds become increasingly argillaceous and frequently are slumped into a steep slope of small lime mudstone nodules and green-grey shale.

Along a north-south trend, the locus for the shift in argillaceous content may differ for the lower and upper trends. At the Fire Sign locality (locality map in figure 1), the upper recessive units form a distinct, tabular to wavy-bedded cliff; nearby at locality N23 and most localities northward, these units are slumped into a steep slope of limestone nodules and shale. Thus, the increase in argillaceous content and change in weathering pattern occurs over only a few km.

The shift below Unit 6 from a more argillaceous but more diverse lithology of the southern section to the consistent but less argillaceous lithology to the north occurs somewhere between localities N18 and N64-65. The addition of new outcrops to the study will help pinpoint a more narrow area of transition.

A shift in fossil assemblages

In general, fossil content decreases above Unit 8 in most of the study area and above unit 6 along the Athabasca River west of Fort McMurray, particularly in the recessive, more argillaceous beds. Fossil assemblages in the upper recessive units decline in diversity and abundance, but the fossils that are present are generally larger compared to that of the lower portion of the section.

Conspicuous fossils characteristic of the assemblages in the lower portion of the section include diverse strophomenide brachiopods, *Eleutherokomma, Radiatrypa*, gastropods, and locally, bryozoans. Upsection, some strophomenide taxa disappear above Unit 5 and the relative abundance of the other brachiopods and gastropods declines in favour of large atrypides and, less commonly, *Schizophoria*. Bryozoans disappear completely, although are only readily observable in the lower beds of outcrops along the Christina River in the south and at outcrops downstream of the barge dock along the Athabasca River in the northern portion of the study area.

Stromatoporoids and biostromes

In the northern portion of the study area, unit 6 contains abundant branching and bulbous stromatoporoids, *Amphipora*, and *Thamnopora* rudstones that interbed with bindstone-forming tabular and lamellar stromatoporoids. Where they exist, these interbedded rudstones and bindstones give Unit 6 a bedded appearance.

Southward along the Athabasca River, tabular and lamellar stromatoporoids decrease in abundance, until only the branching and bulbous morphologies remain. Massive stromatoporoids appear, but are sparse at locality N64-65, and increase in abundance southward at the expense of corals and the other stromatoporoids. Southward, non-massive stromatoporoid morphologies and corals disappear. Along a similar southward trend, massive stromatoporoids increase in size until they reach 50 cm or more in diameter or height, and are domal, cylindrical, “mushroom”, or irregular in shape. By locality N20, only massive stromatoporoids remain of the biostromal fauna.

With the southward-trending changes in the biostromal fauna, the accessory fauna also shifted. The brachiopod *Radiatrypa* is ubiquitous in Unit 6, but becomes very abundant at those localities in which Unit 6 contains only massive stromatoporoids. Between the N20 and Water Treatment Plant localities, massive stromatoporoids are surrounded by a dense concentration of *Radiatrypa.*

This shift from a biostromal assemblage of diverse stromatoporoid morphologies to one dominated by massive stromatoporoids in a matrix of *Radiatrypa* brachiopods reflects a possible gradient towards deeper water, reflecting the change from an inner shelf biostrome to one along the shelf edge consisting of massive, wave-resistant stromatoporoids.

This biostromal gradient experiences one further shift. At the Water Treatment Plant locality, most of the massive stromatoporoids in Unit 6 show signs of transport, particularly abrasion and breakage of the fossils. Westward along the Athabasca River, at the Mountain Rapids and Orange Stripe localities, stromatoporoids are absent, save for a few small fragments of bulbous and/or massive stromatoporoids. Instead of a biostrome, Unit 6 at these localities contains a diverse assemblage of brachiopods, gastropods, and crinoids, and is heavily bioturbated with *Thalassinoides* burrow networks. Thus, these southwestern localities may represent deposits in deeper water than the biostromes.

Three other units in the section also contain stromatoporoids. Units 10 and 12 contain bulbous and/or branching stromatoporoids among a moderately diverse fauna at a single locality each. Unit 2 contains stromatoporoids at most localities throughout the region, but is biostromal only at localities along the Christina and Clearwater rivers. At locality Chr2, the fauna of unit 2 strongly resembles the branching, bulbous, and tabular stromatoporoid faunas of Unit 6 at northern localities.

Conclusions

In the Moberly Member outcrops of the study area, local environmental controls overprint regional patterns in sedimentation. The regional trend of decreasing terrigenous mud to the south is retained in the upper portion of the section, but is reversed in the lower section.

Fossils do not necessarily follow the trends in argillaceous sedimentation, and may be responding to other, as yet undetermined environmental controls.

The biostromal unit (Unit 6 of this study) in the Moberly Member outcrops along the Athabasca River follows a possible trend of deepening in the paleoenvironment from the northeast to southwest, in that a biostrome of branching, bulbous, and tabular stromatoporoid morphologies grades into one dominated by massive stromatoporoids. This biostrome abruptly transitions into a potentially deeper-water environment lacking in stromatoporoids and heavily influenced by *Thalassinoides* bioturbation.

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References

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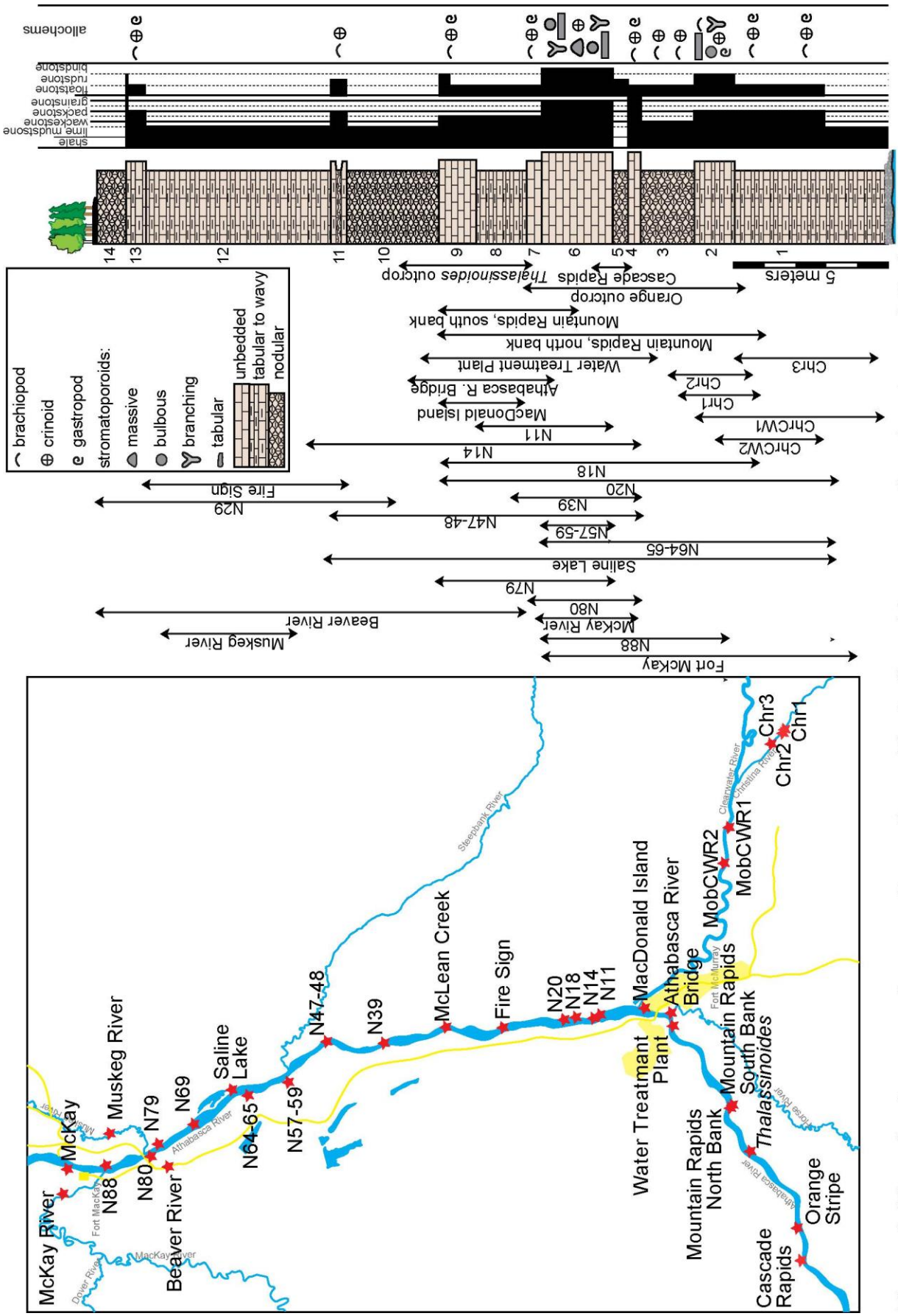

Figure 1. Map of outcrops and composite section, with stratigraphic ranges of each outcrop plotted. Units vary throughout the study area, so each outcrop varies in lithology and thickness from that of the composite section.