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From Subsurface to Outcrop: The Devonian Moberly Member (Waterways Formation) of the Athabasca Oil Sands Region

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Summary

We present a correlation between core and outcrop for the Moberly Member of the Athabasca Oil Sands region. We recognize 5 major facies and 4 main faunas within the section. Two distinctive biostromes exist at two stratigraphic levels and over two smaller regions within the study area that aid in our correlation between outcrop and the subsurface.

Introduction

The Moberly Member (Waterways Formation) outcrops beneath the McMurray Formation along the Athabasca River and adjacent areas in the Fort McMurray and Fort McKay region. These outcrops have long been a popular destination for Devonian stratigraphers and paleontologists, in part because of the rich abundance of lithological, stratigraphic, paleontological, and structural data that can be gleaned from these localities. Previous work into stratigraphic correlation of the Moberly Member within our study area has been presented by Norris (1963) and Cotterill and Hamilton (1995). Here, we present an updated correlation of the Moberly Member in outcrops and core, based on work from 2010 to 2012, in which we describe the facies and fauna, acknowledging the existence of not one, but two biostromal units within the Moberly Member.

For ease of correlation and based on availability of cores, we examined the Moberly Member in cores from wells proximal to the outcrops. In the type core (Bear Biltmore no. 1, 7-11-87-17W4) west of the study area, the Moberly Member is 60.9 m thick. In the study area, the top of the Moberly Member is eroded, and in cores examined, ranges up to 30 m in total thickness from base to eroded top.

Facies

In general, the strata within the study area can be separated into five distinct facies. These facies are colour-coded onto the stratigraphic columns of figure 1.

Facies A: Calcareous shale to very argillaceous lime mudstone

This facies is relatively rare in the Moberly Member, and often occurs stratigraphically adjacent to, or within, Facies B. This facies is usually grey to green-grey in colour and often includes non-bioturbated and argillaceous, cm-scale interbeds or nodules of lime mudstone.

Facies B: Nodular to wavy bedded, bioturbated, argillaceous floatstone

This is the most common facies in the Moberly Member. The argillaceous limestone is often bioturbated, sometimes with pervasive *Thalassinoides* burrow networks. The fossil assemblage is dominated by brachiopods and crinoids, and in the lower portion of the section, can contain molluscs, particularly gastropods. The matrix is usually a wackestone to local packstone of fossil fragments and peloids. Colour varies between grey and beige in core, and is usually beige in outcrop. Argillaceous partings are darker than the limestone, and can comprise up to 15% of the facies.

This facies is more fossiliferous in the lower portion of the section within the study area, particularly below the Athabasca Biostrome. Facies B in the upper portion of the section is poorly fossiliferous, particularly in the northern and southwestern portion of the study area.

This facies frequently contains cm-scale rudstones that formed from tempestite and/or gravity-flow deposits. Faunas in these rudstones can be distinctive and some are correlatable over part of the study area, particularly in the lower portion of the section.

Facies C: Fossiliferous, argillaceous floatstone to rudstone

In outcrop, Facies C usually forms beige, resistant beds. In core, this facies contains argillaceous partings, making the fabric of the rock appear nodular to wavy-bedded. Facies C fossils always include brachiopods and crinoids, but can also include bryozoans, molluscs, stromatoporoids, and corals.

Facies C in core is distinguishable from Facies B by a marked increase in fossil abundance and diversity and more indurated rock. The matrix of Facies C ranges from wackestone to grainstone, but is dominantly a packstone.

Facies D: Stromatoporoid rudstone

Facies D contains abundant stromatoporoids that would have baffled, bound, or created a framework in a biostromal paleoenvironment. Stromatoporoids visibly dominate the fauna in abundance or in size (massive stromatoporoids are up to 50 cm in diameter, in outcrop). Thamnoporoid corals are common where branching and bulbous stromatoporoids are also abundant. Other fossils include brachiopods, crinoids, and gastropods. Brachiopods are most abundant where massive stromatoporoids are present.

This facies is usually beige to light brown in colour, and frequently contains bitumen in the pore space of the stromatoporoids or the matrix.

Facies D occurs only in two units (2 and 6), but neither unit contains this facies over the entire study area. Beyond the margin of the stromatoporoid biostromes, this facies laterally transitions into Facies C, with or without stromatoporoids.

The matrix is a packstone to grainstone. Locally, the matrix is the carbonate sand of Facies E.

Facies E: Carbonate sand grainstone

This facies occasionally forms the grainstone matrix supporting the larger fossils in facies C and D, or was deposited locally as a bed of carbonate sand within facies C or D. Over a large portion of the study area, Unit 4 is almost entirely carbonate sand.

This facies contains fine skeletal debris and peloids, and locally, ooids, grapestones, and rounded intraclasts. The allochems, particularly peloids, are most easily seen in core where they have been weakly phosphatized. In outcrop, weathering usually makes the texture of this facies quite distinct.

Ooid grainstones are not very common in the Moberly Member, but were seen at some outcrops and in several cores. Beds were localized and could not be correlated. Because of its rarity, the ooid grainstone facies is included as a subfacies in facies E, rather than separated into a distinct facies.

Faunas

Four general but distinctive faunas were found in the Moberly Member of the study area. Faunas are labelled on the stratigraphic columns of figure 1.

Fauna A: Stromatoporoid-coral biostrome

Thamnoporoid corals and various morphologies of stromatoporoids are the most abundant organisms in this fauna. Branching forms are most common, and the proportion of corals versus stromatoporoids varies locally. Tabular and lamellar stromatoporoids frequently bind layers of fossil rudstones.

Other fossils include brachiopods, crinoids, and gastropods. *Radiatrypa* is the most common brachiopod encountered.

Stromatoporoids and corals constructed a biostrome of dendroid bafflers and binding tabular and lamellar stromatoporoids. Skeletal debris and micrite formed the matrix between the large fossils.

Fauna B: Massive stromatoporoid-brachiopod bank

In this fauna, massive stromatoporoids up to 0.5 m in diameter “float” in a matrix of closely-packed *Radiatrypa* brachiopods. Stromatoporoids are domal, columnar, or irregular in morphology. Many stromatoporoids bear boreholes and other traces on their surfaces. Brachiopods include whole specimens and single valves, and can form epibole beds of monospecific *Radiatrypa* brachiopods above or below the bank. Other fossils are rare.

This fauna occurs only in unit 6 and laterally transitions into Fauna A to the north and Fauna C to the southwest.

Fauna C: Diverse brachiopod fauna

This fauna is rich in brachiopods, crinoids, and molluscs, and locally contains bulbous and branching stromatoporoids, albeit in lesser abundance than Fauna A. Brachiopods distinct to this fauna are stropheodontoids, chonetidines, and one species of *Schizophoria*. *Eleutherokomma* and *Radiatrypa* are also common, but not exclusive to this fauna. Rare brachiopods include small productides and other atrypides. Locally, gastropods and bivalves are abundant. Crinoid columnals are common throughout.

A higher proportion of brachiopods in this fauna than those in Fauna D are free-lying, compared to pedunculate taxa. Furthermore, fossils in this fauna are usually much more abundant than those of Fauna D. Fauna C occurs mostly within the lower portion of the section.

Fauna D: Large brachiopod fauna

Fauna D typically includes the large atrypides *Desquamatia* and *Pseudoatrypa,* as well as a different, larger species of *Schizophoria* than in Fauna C, the productide *Praewaagenoconcha*, and the ubiquitous *Radiatrypa.* Athyrids are rare, but are more common in this fauna than in Fauna C. Gastropods and bivalves are locally abundant. Like Fauna C, crinoids are common throughout.

This fauna contains a higher proportion of pedunculate to free-lying forms than does Fauna C. Fauna D is common in the upper portion of the section.

Core-to-outcrop correlations

Unsurprisingly, cores contain a more complete Moberly Member section than nearby outcrops within the study area. However, a composite section of the study area captures a substantial part of the Moberly Member succession. When all of the studied outcrops are combined, a composite section for the region extends to almost the base of the Moberly Member (approximately within 1 m).

In outcrop, many units which contain facies A and B are slumped into a slope of limestone nodules. The relationship between facies A and B is better observed in core. Facies D is the most easily correlated facies between outcrop and core; however, because there are two biostromal units within the lower Moberly Member, care must be taken to make sure that the stratigraphically equivalent biostromes are being correlated. Fortunately, the upper biostrome (“Athabasca Biostrome”) is present in the northern portion of the study area, transitioning from Fauna A to Fauna B southward before disappearing west of Fort McMurray. The lower biostrome (“Clearwater Biostrome”) is present only along the Clearwater and Christina rivers, but transitions to Fauna C to the northwest.

In general, faunas are easily recognizable in both outcrop and core. In some cases, such as biostromal faunas, fossils are the key to correlation between the surface and subsurface. In others, such as the brachiopod-dominated faunas C and D, correlations are more difficult, except for the general trends of distinctive faunas in the upper and lower portions of the section.

Conclusions

Because the nodular to wavy bedded floatstone of Facies B is very common, as are the brachiopod-dominated faunas C and D, the biostromal faunas A and B and the stromatoporoid rudstone facies D are the most easily correlated units between core and outcrop. Two biostromal units are present in the section, but their stratigraphic position relative to each other and their regional distribution is distinctive.

Cores contain more or less continuous data for the stratigraphic section that is lost even in a composite section of outcrops. Mainly, highly argillaceous units are slumped in outcrop, but their stratigraphic

position is retained in core. However, the resistance of beds to weathering is a major tool, in addition to their facies and faunas, for recognizing distinct units in outcrop.

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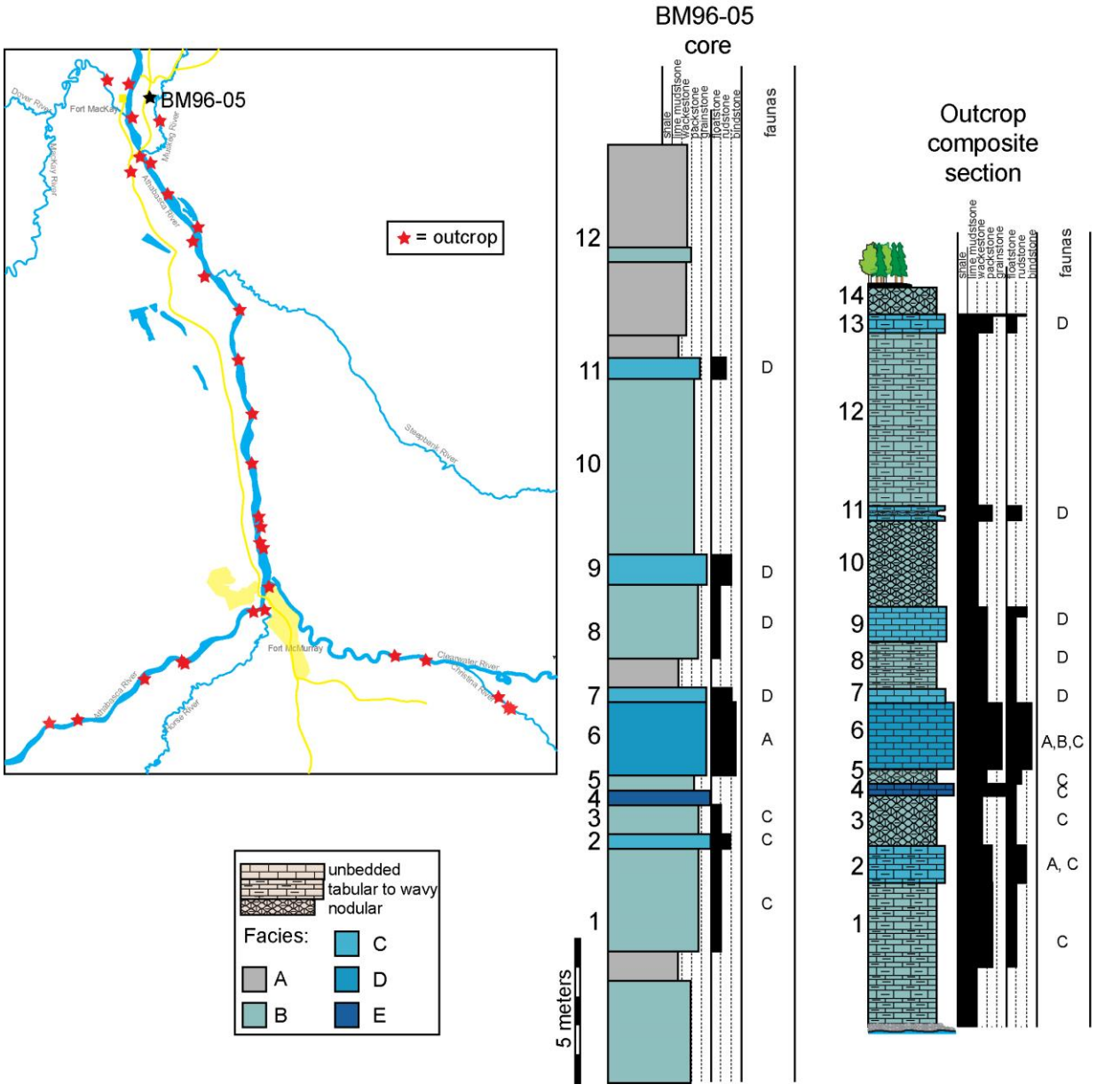

Figure 1. Correlation between core (Birch Mountain core BM96-05, at the Mineral Core Research Facility) and composite section of all outcrops examined in the study area. Variability between core and outcrop is largely driven by the composite section, which is an "average" of lithology and paleontology in outcrops across the study area. Horizontal thickness in the core section represents texture; horizontal thickness in the outcrop section reflects recessive versus resistant beds.