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Application of a Revised Stratigraphic Framework for the McMurray Formation, Southeastern Athabasca Oil Sands Region, Alberta

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Summary

Over the last five years the McMurray Geology Consortim, a collaboration between the University of Calgary, University of Alberta, Simon Fraser University, as well as 5 industry sponsors, has aimed to produce a unifying stratigraphic framework for the Athabasca Oil Sands. The University of Calgary group was initially focused in the southern portion of the deposit where Ranger and Pemberton (1997) and the AEUB (2003) established a functional framework consisting of regionally correlatable marginal deposits incised by extensive channelized units. Building on these studies and leveraging an abundance of new subsurface data, we provide a high-resolution map of the main drainage systems that persisted across a vast portion of the Athabasca Oil Sands Region. In this presentation, we demonstrate the recognition criteria for the main stratigraphic units within the McMurray Formation across the vast (26,000 km^2) study area.

The results of the extensive mapping project provide a framework within which detailed sedimentological investigations, including the evaluation of spatial and temporal variations within stratigraphically distinct fluvial to marginal marine depositional systems, can be undertaken.

Introduction

The McMurray Formation is the major host of in-place bitumen reserves (*ca* 150 billion m^3) in the Athabasca Oil Sands Region (AOSR) of northeastern Alberta. However, exploration and recovery of bitumen is limited by a complex stratigaphic framework, with widespread amalgamation of fluvial and marginal-marine units. Historically, operators have established functional, asset-specific stratigraphic frameworks, however the regional link between assets has often remained elusive, particularly across significant distances. More regionally-focued efforts by Ranger and Pemberton (1997), the AEUB (2003), and Hein and Cotterill (2006) have provided key observations, which include the delineation of regionally correlatable units separated by marine flooding surfaces towards the top of the formation (i.e., parasequence sets of Ranger and Pemberton, 1997), and cross-cutting channel systems that subtend from a series of the flooding surfaces (i.e., valleys of the AEUB, 2003). Building on these studies, the objective of this core presentation is to demonstrate key recognition criteria for the regional parasequence sets and channelized deposits across the vast study area.

Method

A stratigraphic framework and detailed facies scheme for the McMurray Formation across the southeastern AOSR was constructed through the integration of ~13,800 wireline logs and 214 slabbed drill cores across 26,000 km^2 (Hagstrom, 2018; Horner et al., 2018; Martin, 2018). Core observations were integrated with wireline data to calibrate log responses to lithofacies within the McMurrayFormation. Seismic data were used to better constrain the depositinal context of well logs and cores locally.

Stratigraphic Criteria for Applying the Framework

The overall thickness of the McMurray Formation (generally up to 50-100 m) is strongly controlled by the paleo-topography of the underlying sub-Cretaceous angular unconformity surface (Fig.1). Infilling paleotopographic lows on the unconfirmity surface are terrestrial strata historically assigned to the lower McMurray Formation (cf. Carrigy, 1959). The majority of the formation consists of regionally persistent coarsening upwards packages variably incised by channel units. From base to top, these include the McMurray C, B2, B1, A2 and A1 units (Fig.1; Hein and Cotterill, 2006). Although McMurray C parasequence sets and bounding flooding surfaces can be mapped in portions of the McMurray sub-basin, they are not differentiated in this study due to the variable preservation of associated deposits. B2 through A1 parasequence sets are the primary focus, which range from 2-12 m thick and can be correlated across the entire study area.

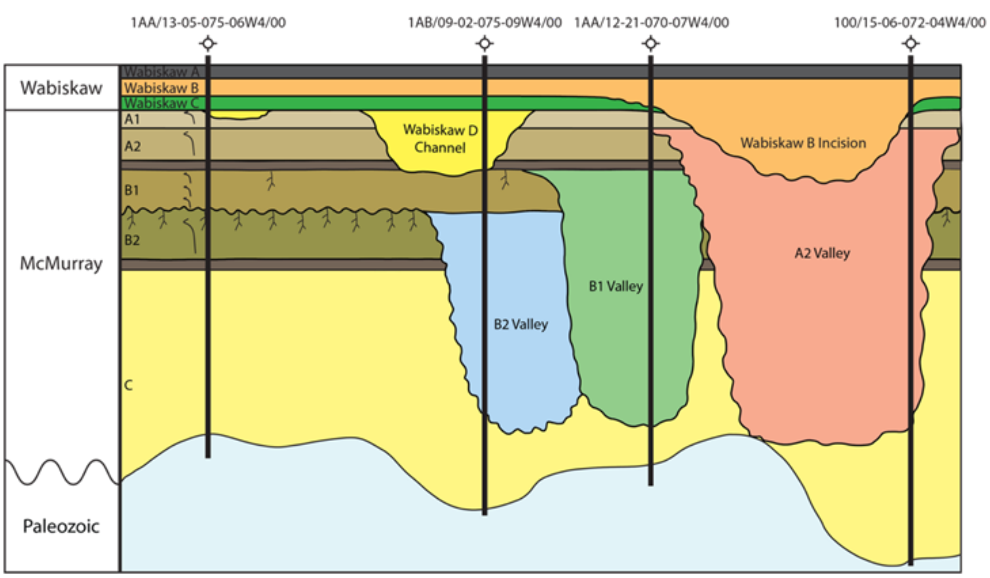

Figure 1. Stratigraphic framework for the McMurray Formation used in this study (originally modified from Hein and Cotterill, 2006 and Horner et al., 2018). The regionally mapped channel systems subtend from multiple stratigraphic levels.

The parasequence sets are locally truncated and removed by channel systems (Fig. 2) up to 50 km wide and 70 m thick, which have variably been attributed to incised valley (e.g., Ranger and Pemberton, 1997; Horner et al., 2018), distributary channel (e.g., Baniuk and Kingsmith, 2018), or channel-belt processes (e.g., Martin et al., *in press*). The presence or absence of the various parasequence sets provides the basis for the recognition of the stratigraphically distinct drainage systems. Where regional parasequence sets are not preserved, they are interpreted to have been locally removed by channelized incision events; the channel systems are generally named based on the regional parasequence set from which they subtend (Figs. 1 and 2; i.e., B2 channel system subtends from the top of the B2 parasequence set). By utilizing the vast dataset, we are able to map the distribution of channel systems in the McMurray Formation at high resolution over a vast area, even where 3D seismic data is not available (Fig. 2).

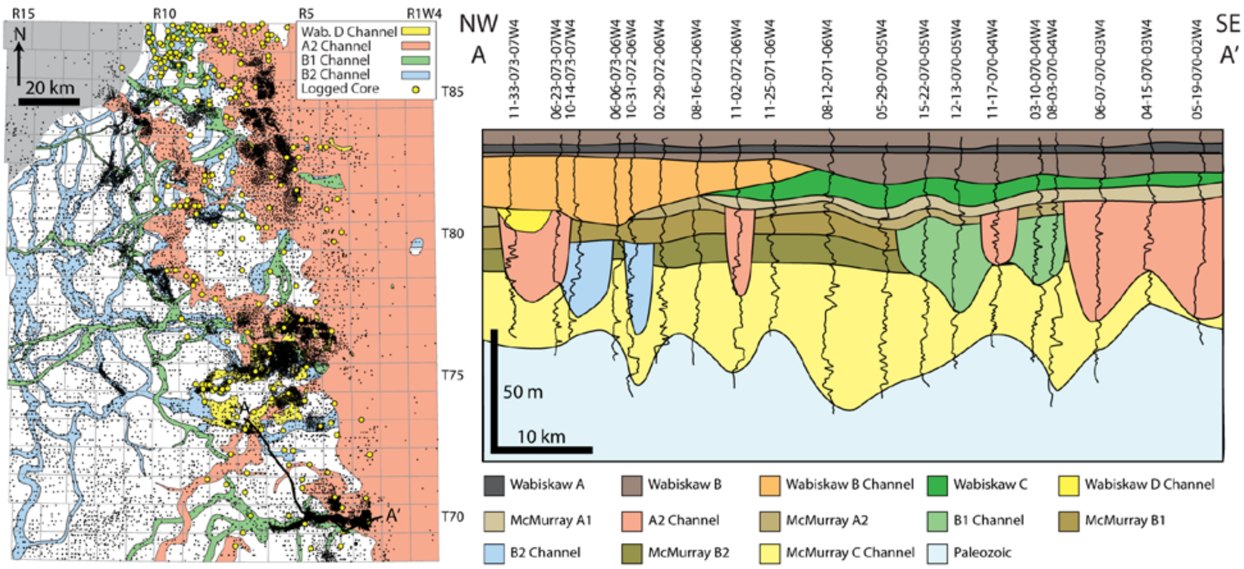

Figure 2. (left) Distribution of mapped channelized systems in study areas (Townships 69-87 and Ranges 1-15 W4M) with the location of cross section A-A'. Areas with the white background have wells that show well-preserved parasequence sets. (right) Cross-section example illustrates the application of the stratigraphic framework shown in Fig. 1 using gamma radiation wireline logs. The recognition of stratigraphically distinct channelized systems is based on the presence or absence of regional parasequence sets.

Marine flooding surfaces are recognized on wireline logs by an abrupt increase in gamma ray values in conjunction with separation in neutron and density logs. The flooding surfaces indicate sharp lithological change from sandstone below to marine mudstone above. Parasequence sets are characterized by variable stratigraphic expressions, with one or more coarsening-upward packages of mudstones grading upwards into interbedded fine-grained sandstones and mudstones most common. Sandstones exhibit a variety of sedimentary structures, such as current ripples, mudstone drapes, wave ripples, and small examples of hummocky and swaley cross stratification. Regionally, the thicknesses of parasequences and parasequence sets can be used to provide insight into shoreline migration histories. Channel systems are dominated by upwards fining point bar deposits, commonly associated with inclined heterolithic stratification. Seismic data from the A2 valley corroborates sedimentological observations and reveals that fluvial sedimentary processes largely responsible for the observed intra-channel system stratigraphic architectures in the southern Athabasca Oil Sands area (e.g., Durkin et al., 2018; Hagstrom et al., 2019).

Conclusions

Application of the revised stratigraphic framework for the McMurray Formation facilitates delineation of ancient drainage systems over almost 200 km along depositional dip, and can be utilized to identify upstream-downstream sedimentological, ichnological, and morphological trends characteristic of fluvial and marginal marine depositional settings. Therefore, the established stratigraphic framework provides an obvious foundation from which to build more honed, regionally consistent interpretations of the paleogeographic setting through time.

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