IHS Development in a Tidally Influenced River, Fraser River, British Columbia*

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Abstract

The McMurray Fm of the Western Canada Sedimentary Basin, Alberta, forms a significant bitumen reservoir in the Alberta oil sands. Predicting the lateral and vertical extent of mud beds in Middle McMurray Fm inclined heterolithic stratification (IHS) is necessary to ensure the economic viability of hydrocarbon extraction from these deposits. However, in core it is difficult to determine the continuity of mud beds and muddy successions because of limited data. This is not the case in modern settings. To assess the continuity of mud beds and mud-dominated units, a mid-channel bar (detached point bar) in the mesotidal reach of the Fraser River, British Columbia was studied. The distribution of mud and sand beds across the bar, and the sedimentological and ichnological character of these deposits were determined. The overall point bar succession exhibits a fining-upward profile with an increase in mud-bed thickness from the shallow subtidal to the upper intertidal zone. A fining-downstream trend is observed around the bar, due to an increase in mud-bed thickness in the downstream direction. In addition, mud beds in the shallow subtidal zone are much more laterally continuous on the downstream end of the bar, with some beds being correlateable distances greater than 1 km.

A low diversity assemblage of diminutive infauna-generated burrows characterizes the ichnology of the system. Where present, bioturbated horizons tend to be rhythmic in nature, reflecting annual cyclicity in environmental stresses. Burrowing is limited to the muddy horizons, or extends down from muddy horizons into underlying sand beds.

Sand is mainly transported in the late spring and early summer, when river discharge increases by nearly an order of magnitude due to the flood stage freshet. Throughout the remainder of the year, relatively low flow conditions ensue, enabling the accumulation of fine-grained (muddy)
sediments, and the establishment of stable brackish-water conditions. The latter is favourable for infaunal colonization.

The depositional model presented herein may prove to be a useful tool for hydrocarbon exploitation by providing an analog model for predicting lithological heterogeneities (i.e. lateral and vertical extent of mud beds). In particular, the IHS developed in the tide-influenced reach of the Fraser River may prove beneficial in predicting along- and across-strike changes in mud distribution of Middle McMurray Fm point bars.

References


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Abstract
Inclined heterolithic stratification (IHS) is developed on a laterally accreting channel bar in the tide-influenced, fluvially dominated reach of the Fraser River, British Columbia, Canada. A fining-upward profile with an increase in mud-bed thickness and mud content, from the shallow subtidal to the upper intertidal zone, defines the vertical bar succession. There is an increase in the number of mud beds and the lateral continuity of mud beds from the upstream to the downstream side of the bar. These sand-mud interbeds are more regularly distributed in this tide-influenced setting than it is reported from IHS in purely fluvial settings. Moreover, the rhythmicity of the interbedding typical of tide-dominated point bars is not observed. (Sand deposition occurs during high discharge e.g. snow melt-induced flood) and the sand bars are ephemeral and rapidly deposited during low discharge (ambient flow conditions). This cyclicity is further observed in the ichnological character of the bar, where burrows are evident in mud beds or sand turbidites, but rare in sand beds. Where burrows occur in sand, they extend down from overlying mud beds. Burrows are mainly of vertical form, reflecting a very low diversity of burrowing organisms. In the sand bars, burrows are more common on the downstream side of the bar, where mud beds are thicker and more laterally continuous. The variability in the sedimentology and ichnology of the upstream and downstream sides of the bar may prove to be a valuable tool for predicting the lateral and vertical extent of mud beds in similar IHS deposits in the rock record, such as the McMurry Formation of the Western Canadian Sedimentary Basin.

Geological Setting
1) The Fraser River (200 km²) shingle basin
2) The Fraser River Delta (990 km²) lagoonal estuary
3) Fraser River Delta, deltaic depositional history

Hydrodynamics
6) Annual discharge pattern of Fraser River showing spate in discharge and suspended load due to annual spring snowmelt flood, and return to low flow conditions
5) Data distribution and channel flow direction (solute)
4) Sediment sizes (s) in m,abs (top layer)
3) Cross-sections and subaerial deposition history
2) Salt wedge position during ambient and flood flow conditions (Fig. 2 shows location)

Sedimentology
10) Basal muds interchange with freshwater-marine turbidity in foreland
9) Large slump beds in channel banks 40 cm in scale, 5 m in depth
8) Active margins of channel margins and submerged gravel terraces
7) Erosional scarps exposing laminated beds and very fine sand. This results in mud beds that are more continuous alongshore with a sand bar
6) Wackestone / Bioturbated mud and sand with overall fining-upward profile. Sand beds in the shallow subtidal portion of the bar can be composed of both bioturbations, plant structures or have a more marine appearance.

Seasonal Deposition
4) Photos of same location
14) Sand deposition on current-swept surface of the intertidal zone during flood.
15) Mud deposition on mud-covered surface after months of ambient flow conditions

channel depth and grain size distribution
16) Channel depth: the channel has an average depth of 1.5 m along the accretionary edge of the bar.
17) Grain size distribution: the channel exhibits a fine-sand to fine-silt sized sand to the base of the channel, passing upward into laminated mud and unsorted mud deposits. The depositional processes range between gravel and fine sand and matrix supported sand and silt to fine sand and matrix supported mud and silt to fine mud and matrix supported silt to fine mud. Sample locations are shown in Table 2 and Figure 1. The bar is 0.5 m thick and is found below the mean low water mark (MLW). Cross Sections
1) Cross section profiles by location
2) Downstream: This side of the bar is sandy with the mud on top below the mean low water mark (MLW)
3) Upland: This side of the bar is sandy with low mud on top below the mean low water mark (MLW)

Conclusions
1) Inclined heterolithic stratification (IHS) in the tidally influenced reaches of the Fraser River reflects seasonal cyclicity in sediment deposition. Sand beds are deposited during flood (greater flow conditions) and mud beds are deposited during the rest of the year (sustained and ambient flow).
2) Mud bed frequency, thickness, and lateral continuity increase from the upstream to downstream end of the bar, and increase as the channel base to top. Mud beds are more laterally continuous alongshore than in a dip-oriented direction.
3) Bioturbation is characterized by a low diversity trace fossil assemblage of diminutive burrows, with locally abundant trace densities. This ichnological signature is typical of highly saline-stressed environments (over 200 ppt of salinity).
4) Bioturbation is strongly substrate-controlled with burrows more prevalent in mud beds. This reflects annual recolonization of bar sediments under ambient flow conditions (periods of mud deposition).
5) This style of interbedded sand and mud, and annual recolonization of mud beds, reflects the seasonal cycle of river discharge in the tide-influenced, fluvially dominated lower reaches of the Fraser River.

References

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