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

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Search and Discovery Article #50373 (2011)
Posted January 18, 2011

*Adapted from poster presentation at AAPG International Conference and Exhibition, Calgary, Alberta, Canada, September 12-15, 2010

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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.

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Abstract

Inclined heterolithic stratification (IHS) is developed on a laterally accreting in-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 is reported from IHS in purely fluvial settings. Moreover, the rhythmicity of the interbedding typical of tide-dominated point bars is not observed.

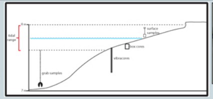
Sand deposition occurs during high discharge (e.g., snowmelt-induced freshet), and laminated mud beds are deposited during low discharge (ambient flow conditions). This cyclicity is further observed in the ichnological character of the beds, where burrows are evident in muddy intervals, but rare in sand beds. Where burrows occur in sand, they extend down from overlying mud beds. Burrows are mainly diminutive, vertical forms, reflecting a very low diversity of burrowing organisms in the channels. 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 McMurray Formation of the Western Canada Sedimentary Basin.

Geological Setting

1) The Fraser River's 250 000 km^2 drainage basin
2) The Fraser River Delta (study area indicated)
3) Fraser River Delta's depositional history

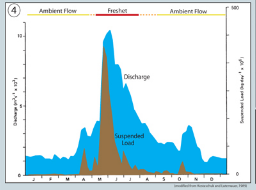
Methods

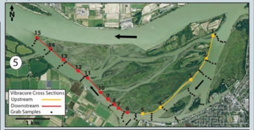
- grab samples
- vibracores
- box cores
- surface samples

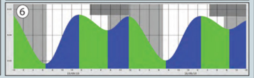


Hydrodynamics

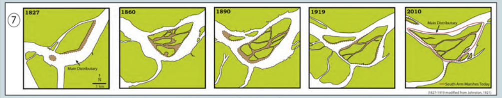
4) Annual discharge pattern of Fraser River showing spike in discharge and suspended load due to annual spring snowmelt freshet, and return to low flow (ambient) conditions.
5) Data distribution and channel flow direction (ebb)
6) Example of tides (3 m mean tidal range)



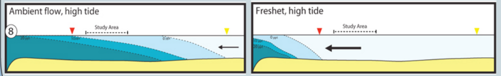




7) Main distributary avulsion and study area depositional history

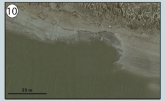


8) Salt wedge position during ambient and freshet flow conditions (Fig. 2 shows location)



Sedimentology

9) Slumping marsh deposits, with flaser-bedded wave ripples in foreground.
10) Large slump scar in channel bank (40 m across, 5 m deep).
11) Active erosion of channel margin producing mud clasts.
12) Erosional scarp exposing laminated muds and very fine sand. This results in mud beds that are more continuous along-strike than in a dip-orientation.
13) Vibracore 8 - Interbedded mud and sand, with overall fining-upward profile. Sand beds in the shallow subtidal portion of the bar can be comprised of stacked current ripples, planar laminations, or have a massive appearance.



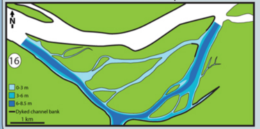
Seasonal Deposition

• Photos of same location

14) Sand deposition: current-rippled surface of the intertidal zone during freshet.
15) Mud deposition: mud covered surface after months of ambient flow conditions.

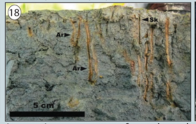
Channel Depth and Grain Size Distribution

16) Channel depth: the channel has an average depth of 7m along the accreting edge of the bar.
17) Grain size distribution: the channel exhibits a fining upward trend from coarse/medium sand at the base of the channel, passing upward into laminated mud and vegetated marsh deposits. The downstream portion of the bar shows an increased amount of mud, mainly in the intertidal and shallow subtidal zone. Samples taken in June and July, see Fig. 5 for sample locations.

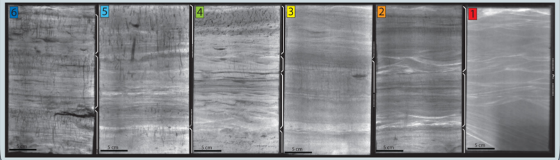


Ichnology

18) Diminutive *Arenicolites* and *Skolithos* burrows penetrating downward from mud bed at surface. The presence of the trace maker, *Corophium*, was negligible throughout freshet, and abundant by late winter (annual post-freshet recolonization).
19) Lined *Arenicolites* burrow produced by *Nereis* polychaete. This trace maker was only present during ambient conditions.



20) Box cores 1-6 showing an increasing amount of mud, and bioturbation, from upstream to downstream (substrate-controlled bioturbation). Brackets indicate interpretations of annual depositional packages identified by the presence of bioturbation. The rhythmic nature (most evident in 2, 4, 5 and 6) is due to annual recolonization of the sediments post-freshet.

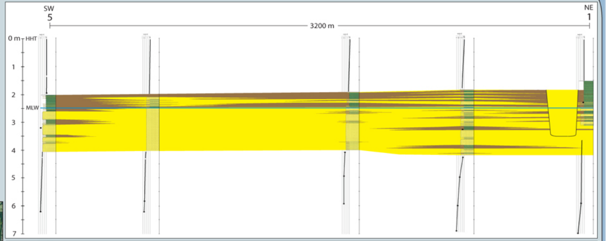


Cross Sections

- Grain size profiles beyond cores constructed from channel grab samples, contour mapping, and intertidal zone surface observations.

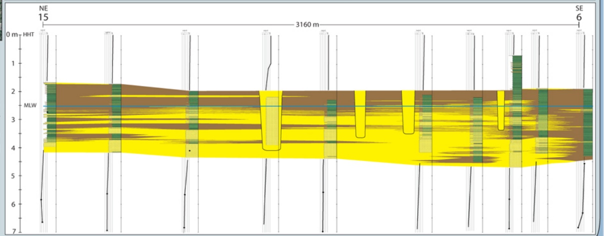
Upstream

This side of the bar is sandier, with few mud beds below the mean low water line (MLW).



Downstream

This side of the bar shows an increase in the number of mud beds, and an increase in mud bed lateral continuity.



Conclusions

1) IHS development in the tidally influenced reaches of the Fraser River reflects seasonal cyclicity in sediment deposition. Sand beds are deposited during freshet (elevated flow), mud beds are deposited during the rest of the year (waning and ambient flow).

2) Mud bed frequency, thickness, and lateral continuity increase from the upstream to downstream end of the bar, and from channel base to top. Mud beds are more laterally continuous along-strike 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 salinity-stressed environments (oligohaline to mesohaline, 0-10 ppt).

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 the annual recolonization of mud beds, reflects the seasonal cycle of river discharge in the tide-influenced, fluvially dominated lower reaches of the Fraser River.

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Acknowledgements

We kindly thank these organizations for their financial support.
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