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Linking Channel Margin Sedimentation to Hydrodynamics Across the Tidal-Fluvial Transition, Lower Fraser River, BC, Canada

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Summary

The Fraser River, BC is entirely undammed along its length, and is subject to strong tidal flow in its lower reaches. As a result, sedimentation in the lower Fraser River reflects the complex interplay of river discharge and tidal flux, and concomitant variations in the degree of saltwater – freshwater mixing. Local hydrodynamic conditions in the channels vary considerably, and ultimately determine the distribution of sand and mud, with mud concentrated in the turbidity maximum zone (TMZ). The TMZ shifts position significantly with changes in river discharge, and extends along the entire boundary between the saltwater wedge and the overlying freshwater plume. Vibracores were collected from several channel bars in the freshwater-tidal and brackish-water-tidal reaches of the Fraser River, with the goal of linking the observed variability in IHS character across the tidal-fluvial transition to the causative hydrodynamic conditions.

In cores collected from the freshwater tidal reach near Fort Langley, sands are generally thick (dm to m), and range from trough cross-bedded in the lower subtidal zone to current ripple laminated in the upper subtidal or intertidal zones. Muds are thin (cm to dm) and laterally continuous for metres to tens of metres. Muds accumulate in the middle to upper intertidal zone, and are either planar laminated, reflecting suspension settling during base-flow conditions, or form low-amplitude floccule-sand current ripples, indicating traction transport and deposition during the waning stages of the freshet. Depositional cyclicity between sands and muds is poorly developed; only in rare instances can tidal influence be discerned by counting mud or carbonaceous laminae on dune foresets. Bioturbation is absent in sands and sparse (BI 0-1) in muds, and consists of rare, horizontal deposit-feeding traces (e.g., *Planolites*) produced by freshwater oligochaetes.

At the transition from the freshwater-tidal to brackish-water-tidal reach, at Port Mann, sands are thinner (cm- to dm-scale), and are characterized by current-ripple lamination and less common trough cross-bedding in the upper subtidal and lower intertidal zones. Muds are thicker (dm to m) and muddy bedsets can span hundreds of metres to kilometres laterally. They are deposited only in the uppermost subtidal and intertidal zones, and are planar laminated or show floccule-sand current ripples. In this part of the system, channel bars consist of more than 50% mud in the intertidal zone, as deposition occurs near the time-averaged maximum landward position of the TMZ. Nevertheless, bedding cyclicity is not well expressed due to the dominance of fluvial processes. Bioturbation is largely absent in the sands, but displays low intensities (BI 0-2) and patchy distributions in the muds. Traces consist of vertical dwellings (e.g., *Skolithos, Polykladichnus*) subtending into muds from sand-mud contacts, produced by salinity-tolerant polychaetes, and/or horizontal deposit-feeding forms (e.g., *Planolites*) created by polychaetes or freshwater oligochaetes.

In the brackish-water and strongly tide-influenced reach at Canoe Pass and the South Arm Marshes, sand beds are decimetres to metres in thickness. The sands are trough cross-bedded lower on channel profiles, but may also occur as centimetre-thick planar interbeds within mud-dominated successions. Muddy units are generally cm-scale, although locally they reach m-scale thicknesses. Mud-dominated units extend laterally for tens to hundreds of metres. They comprise stacked floccule ripples and wavy-parallel laminae, with subordinate numbers of structureless and deformed layers. These sedimentological features reflect dynamic mud deposition during late-stage freshet and during base flow conditions. A weak, seasonally induced cyclicity to the sand and mud interbeds is developed, and in rare instances, tidal rhythmicity can be demonstrated. Bioturbation is concentrated in mud beds, with bioturbation intensities ranging from BI 1-3. Burrows are patchily distributed. The trace suite comprises diminutive deposit-feeding (e.g., *Planolites, Teichichnus*) and more commonly dwelling (e.g., *Skolithos, Polykladichnus*) structures produced by polychaetes or small bivalves. Burrows are rarely observed in the sands.

Comparing the sedimentology and ichnology of channel bars across the tidal-fluvial transition and linking these characteristics to hydrodynamic conditions constitutes the first step in developing a process-response facies model for fluvial-dominated, tide influenced river systems. From this work, we identify characteristics that reflect increasing tidal and brackish-water influence, including: 1) increasing bioturbation intensity and burrow distribution; 2) increasing size and diversity of traces; 3) increasing thicknesses and lateral continuity of mud beds towards the turbidity maximum zone; 4) increasing occurrence of dynamic mud deposition (i.e., at flow velocities typically associated with sand deposition); and 5) increasing occurrence of seasonal and tidal depositional cyclicity between sands and muds. However, these trends do not necessarily extend from the tidal-fluvial transition into the tide-dominated part of the system. The conclusions derived from the Fraser River are of fundamental importance to the production of unconventional hydrocarbons from tidal-fluvial reservoirs such as the McMurray Formation, because the characteristics of channel-margin deposits (i.e., IHS) controls reservoir heterogeneity and ultimately, reservoir compartmentalization. The Fraser River is one example of quantified sedimentological, ichnological and lithological distributions in a tidal-fluvial system, and helps build towards the development of process-based models that can be used to predict mud distributions beyond the wellbore.