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Towards a Process-Response Facies Model for IHS Deposited in Tidally Influenced Rivers Using the Fraser River, BC as an Analog

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Abstract

A modern study of inclined heterolithic stratification (IHS) from the Fraser River is undertaken to address a deficiency in our understanding of the sedimentological processes and animal-sediment responses that occur on channel bars across the tidal-fluvial transition. The depositional processes operating in the Fraser River can be observed and measured directly, allowing for the establishment of process-response linkages. As IHS-prone reservoirs are volumetrically important in hydrocarbon-producing reservoirs (e.g., McMurray Formation), reservoir heterogeneity and compartmentalization are best understood in the context of depositional processes. This study provides an important step towards developing a refined facies model for IHS-dominated strata with the aim of reducing uncertainty in reservoir and flow modeling beyond the well bore. To carry out analysis of Fraser River IHS, vibracores, box cores, and surface sediment samples were collected from nine channel bars and grouped into three zones. The three zones share similar hydrodynamic and water salinity conditions: a tidally influenced freshwater zone, a tidally influenced freshwater to brackish-water transition zone and a mixed tidal-fluvial with sustained brackish-water zone. Data was collected for identifying sedimentological and ichnological characteristics that define channel-bar deposits and that can be used to predict depositional environments of tidally influenced channel deposits in the rock record.

In the freshwater-tidal zone, bars primarily consist of sand. Sand beds/bedsets are m-scale, and consist of trough cross-stratification at subtidal depths, passing upwards into current- or climbing-ripples in the intertidal zone. Mud beds are rare, and muddy bedsets rarely exceed 5 cm thick. Mud beds/bedsets are confined to intertidal levels. Bioturbation ranges from BI 0–1, and *Planolites* in mud beds or irregular oligochaetes-produced burrows, are the only observed traces. Near the freshwater to brackish-water transition, the upper subtidal and intertidal portions of bars become increasingly mud dominated, and muddy bedsets range from cm- to m-thick. Discontinuous cm-scale sands are sporadically distributed within mud-dominated intervals. The characteristics of mud beds reflect deposition from energetic currents with either high suspended-sediment concentrations and/or from flocculation. Preserved mud on ripple foresets may be the result of bedload-transported floccules or suspended mud deposited on the leeward side of ripples. Bioturbation varies from BI 1–3, is sporadic, and consists of *Polykladichnus*, *Skolithos*, and *Arenicolites*. These burrows primarily occur in muddy layers, but also commonly subtend into underlying sand beds. In the mixed tidal-fluvial zone with sustained brackish-water, bars have subequal proportions of sand and mud. Sand beds are dm- to m-scale, whereas mud beds are generally cm-scale. Trough cross-stratified sands are typical of subtidal channel and bar deposits, and current ripples with common mud flasers characterize sands in the intertidal zone. Muds are either bioturbated or laminated, and are restricted to the uppermost subtidal or intertidal zones. Bioturbation ranges from BI 0–3, consisting mainly of burrows in the mud beds (e.g., *Skolithos*, *Arenicolites*, *Polykladichnus*, and *Planolites*). Burrows commonly cross cut sand beds and bedsets.

A series of trends are identified that link the sedimentology and ichnology of channel bars to the hydrodynamic and water salinity conditions across the tidal-fluvial transition. Key characteristics that reflect increasing tidal and brackish-water influence include:

(1) Increasing bioturbation intensity. More stable interstitial water salinities promote colonization by salinity-tolerant organisms.
(2) Increasing size and diversity of traces reflecting a progression from the near absence of infauna on channel bars in the freshwater zone to a more typical “brackish-water suite” near the river mouth;
(3) Increasing thickness and lateral continuity of mud beds towards the brackish-water to freshwater transition. This is primarily a function of the development of a turbidity maximum near the landward edge of the saltwater wedge;
(4) Increasing depositional cyclicity between sand and mud beds towards the turbidity maximum zone (i.e., within the freshwater to brackish-water transition zone) and seaward.

These four trends defined herein provide a means to determine the paleogeographic position of channel bars and relative influence of tides and brackish-water conditions on their deposits. Through this, a greater fidelity in paleoenvironmental interpretations for IHS successions in the rock record can be made. Ultimately, the process-response facies model developed from the Fraser River provides quantified data for the proportion of sand and mud in IHS, the expected thickness ranges of sand and mud beds, and the lateral relationships between facies. In conjunction with similar studies from other river systems, it should be possible to define the range of bedset-scale heterogeneities that can occur in IHS-prone reservoirs.