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A comparison of the sedimentological, ichnological, palynological and geochemical characteristics of channel-margin sediments across the tidal-fluvial transition of the lower Fraser River, British Columbia

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Summary

The lower reaches of the Fraser River, BC are tidally influenced, and experience strong seasonal variability in river discharge. The maximum upstream incursion of saltwater (as a saltwater wedge) up the distributaries shifts significantly depending on the relative strength of tidal versus fluvial flow. Sand and mud deposition on the channel margins is determined by the duration and magnitude of saline water at the bed, with mud being deposited primarily in the turbidity maximum zone. The turbidity maximum zone extends along the contact between the saltwater wedge and the overlying freshwater plume. Herein we compare palynological and geochemical signatures to sedimentological and ichnological characteristics of intertidally exposed sediments across the tidal-fluvial transition. Palynological datasets include pollen, spore, and dinoflagellate cyst abundances. Geochemical data is limited to C^{13} isotope enrichment ($\delta^{13}C$) in the sediments. Sedimentological and ichnological data provide *in situ* evidence of hydrodynamic conditions and salinity conditions at the time of sediment deposition and/or colonization. The comparison of these datasets is done to determine which physical characteristics (sedimentology, ichnology, palynology, and/or geochemistry) best reflect depositional conditions, and to determine the magnitude of change in sediment characteristics with changes in tidal versus fluvial flow and with changing salinity. In the rock record, these data can be used as analogs to similar deposits, such as inclined heterolithic stratification (IHS) successions in the middle McMurray Formation, Alberta.

The lower Fraser River is divided into three zones – freshwater-tidal, fresh- to brackish-water transition, and brackish-water-tidal – based on hydrodynamic and salinity conditions along the river. The boundaries between these zones are gradational. In the freshwater-tidal zone, mud beds and bedsets are thin (cm- to dm-scale), and are commonly planar laminated or show subordinate low-amplitude floccule-sand current ripples. Bioturbation is sparse in these muds (Bioturbation Index (BI) 0-1), and primarily consists of diminutive, horizontal traces (*Planolites*). This zone has the lowest average concentration of dinocysts (0.48%). The sediment geochemistry shows elevated $\delta^{13}C$ values, but these results are attributed to local anthropogenic influence.

The fresh- to brackish-water transition zone is positioned around the average to maximum upstream position of the saltwater wedge during base flow (nine months of the year). In intertidal positions of the transition zone, mud accumulates in dm- to m-thick beds and bedsets. Planar lamination is the dominant sedimentary structure and floccule-sand current ripples are comparatively more common than in the freshwater-tidal zone. Bioturbation is sparse (BI 0-2), with patchy distributions in mud beds and none in sand beds. The trace suite consists of vertical dwelling structures (*Skolithos, Polykladichnus*) that subtend from sand-mud contacts, and/or horizontal burrow networks (*Planolites*). Average dinocyst concentrations are 0.54% of the total palynomorph population, and the average $\delta^{13}C$ value in muds is $-26.06^{0}/_{00.}$ These data compare with control samples from the Fraser delta front, which exhibit an average dinocyst concentration of 2.93% and a $\delta^{13}C$ value of $-23.30^{0}/_{00}$.

In the brackish-water-tidal zone, mud beds and bedsets range from cm-scale to m-scale, depending upon local fluvial discharge. Sedimentologically, muddy successions comprise stacked floccule ripples and wavy-parallel laminae, with subordinate structureless and deformed layers. Bioturbation intensities range from BI 1-3 in mud beds and muddy bedsets, and burrows are distributed irregularly. The trace suite comprises vertical structures (*Skolithos, Polykladichnus*), with fewer diminutive horizontal burrow networks (*Planolites, Teichichnus*). Dinocysts comprise 0.74%, on average, of each palynological assemblage, and $\delta^{13}C$ values average $-25.65^{0}/_{00}$.

Across the tidal-fluvial transition of the lower Fraser River, several trends in the ichnological, palynological, and geochemical data are observed. The ichnological signature changes from patchy and sparse bioturbation (BI 0-1) dominated by diminutive horizontal structures in the freshwater reach, to more evenly distributed and denser burrowing (BI 1-3) in the brackish-water-tidal zone. In the brackish-water tidal zone, the traces are mainly vertical burrows, with subordinate horizontal burrow networks. The progressive changes downstream in the ichnological character appear to reflect the duration and magnitude of saline water incursion at the bed, as well as deposition rates. Palynological suites show low populations of dinocysts throughout the study area and, where present, marine and salinity-tolerant dinocyst populations increase in the seaward direction. Furthermore, sediment samples are increasingly enriched with $\delta^{13}C$ in the seaward direction, reflecting higher concentrations of marine-derived organic carbon. The palynology and geochemistry of the muds through the tidal-fluvial transition suggest that the provenance of organic matter is dominantly terrestrial, with subordinate marine influence.

In the Fraser River, the lateral and vertical distribution of mud beds on the channel margins is strongly linked to the degree of brackish-water influence and to the relative strength of tidal versus fluvial flow. In addition, the ichnological, palynological, and geochemical signatures of muds are particularly sensitive to water salinity (i.e., fresh versus brackish). By using the well-defined changes in physical characteristics of sediments through the tidal-fluvial transition – increasing bioturbation intensity and diversity, increasing populations of marine and salinity-tolerant dinocysts, and progressive enrichment of $\delta^{13}C$ in the basinward direction – it is possible to establish the relative magnitude of brackish-water influence on sediment deposition, which can then be used to predict the thickness and lateral extent of mud beds. Although more modern analogs are needed to test these results, the link between mud distributions, physical sediment characteristics, and depositional conditions indicates that it should be possible to predict mud-bed extents and thicknesses using only the physical characteristics of the sediments. In the rock record, particularly in IHS-prone successions, predicting the lateral extent of mud beds from physical characteristics of sediments, would help with well placements, and would likely lead to the discovery of new economic resources.