The enigma of point bars deposited in the fluvial-tidal transition – What new research directions does the oil industry require to better understand the Athabasca Oil Sands

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The Cretaceous Athabasca oil sands in western Canada are the 2nd largest hydrocarbon resource on earth. Most of that resource is located in the deposits of the McMurray Formation, in multi-story, tidally influenced, meandering river point bars having highly variable lithology and morphology.

This talk presents a series of vignettes illustrating the various depositional styles of point bars found in the Athabasca oil sands. Data sets include high-resolution seismic slices and cross sections, detailed core measurements, and wire line and image logs. Sedimentological, ichnological associations and palynological recovery indicates that deposition occurred in a zone of tidal-fluvial transition; tidal indicators are rare to common.

The point bars of the McMurray Formation were deposited within a highly dynamic and migratory, low accommodation depositional system. Fluctuating relative sea level resulted in multiple incised valley systems. Subsequent valley fill resulted in a vertical stacking pattern of multiple depositional units or storeys.

High-resolution seismic imagery shows that the rivers that deposited these point bars had variable sinuosity (1.6 to 2.5). The point bars migrated both by lateral accretion and by downstream translation. Core and log data show single channel deposits or storeys up to 48 m thick. The rivers, as indicated by well-preserved and imaged mud plugs were up to 600 m wide. Sand grain size is generally fine grained, although lower channels and channel bases may reach pebble size. Facies relationships, depositional elements and paleontology (ichnology and palynology) variably suggest diurnal, spring to neap cyclicity and seasonal components to the sediments.

Generally, there is minimal evidence of levees or conventional overbank deposits. Roots and paleosols are not common; where the latter do occur, they tend to be well developed and associated with the interfluves of incised valleys.

Non-reservoir muds occur as continuous to discontinuous, likely seasonally deposited mudstone layers on inclined heterolithic stratification (IHS); thinner centimeter-scale muds associated with spring to neap cyclicity; and millimeter-scale slack water deposits. Channel bottom muds may be fluid muds. Abandoned channel mud plugs associated with chute and neck cutoffs are an integral part of the deposition system as are alternating, low angle IHS. These muds may act as barrier or baffles during hydrocarbon production.

Erosional surfaces, found at the base and within point bar successions, may be the result of channel readjustment associated with high-energy flood events or other perturbations within the system. Elsewhere they are the result of avulsion and migration processes.

In these tidally influenced point bars, sand concentrations seem to be concentrated at various positions in the point bars. Downstream fining is common; counter point bars are silty; some point bars are muddier at their apex.

Several point bar morphological elements are observed from the data sets. Sand-dominated side bars are deposited along the inner edge of, but detached from, the point bar. Preservation of the side bar is enhanced by channel abandonment, whereby the side bar is draped by and onlapped by silts of the mud plug. Counter point bars, characterized by high silt content, occur downstream of sandy point bars. These counter point bars are most easily identified morphologically and by their relationship to point bars using seismic imagery. Elsewhere, abandoned, migratory point bars become re-occupied through the process of chute-channel capture. Upon subsequent abandonment, the chute channel then becomes mud-filled. In rare cases, channels filled with reservoir quality sand, rather than mud, upon abandonment; the mechanism for this type of deposition is not well understood. The depositional fabric in these features appears to be dominated by unidirectional dune-scale bed forms preserving the direction of paleoflow.

Mud clast breccias typify the McMurray Formation. Breccias occur as rounded to angular siltstone clasts from centimeter to metre scale within beds of variable thickness. The breccias are typically surrounded by oil saturated fine-grained sands, although in some instances, there is no matrix. The breccias are the result of bank collapse, erosion of mud layers on IHS beds and possibly on chute-channel surfaces. Breccia beds are highly variable and are difficult to resolve seismically.

What does the oil industry require to better understand the McMurray point bar reservoirs? In general, existing fluvial studies and models do not take into account tidal influence, nor do those studying the coastal zone commonly penetrate landward 50 to 100 km or more to study the tidal-fluvial transition. What the industry needs in order to more efficiently produce this bitumen resource is a better understanding of the mixing of tidal and fluvial processes, in addition to the importance of seasonality and longer-term climate cyclicity in this setting. Currently, there is not a solid comprehension of the fluid and sediment dynamics in tidal-fluvial transitional systems. We are still looking for appropriate analogs to add to our data bases. What are the mixed tidal and fluvial depositional processes and the resulting sediment variability, both laterally and vertically?