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The Good, The Potential And The Ugly: Three Different Point Bar Lithofacies in Modern Meandering Tidal-Influenced Rivers: Ideas Applied To SAGD McMurray Oil Sands

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Introduction

Three different point bar lithofacies associated with reservoir quality in meandering river lateral accretion deposits are recognized from research in the modern tidal-influenced river deposits in the lower Chehalis River, SW Washington State. The studied channel meander and point bar system is located 33 km inland from the Pacific Ocean and 8 km upvalley from the community of Aberdeen. The study area has a maximum tide range of 3.5 m, and a twice-daily tidal reversal during Spring, Summer and Fall seasons, but is unidirectional during the Winter months when rainstorms dominate the river hydrologic regime. Here, we used vibracoring, hand-dug trenches, a Lane bottom drag sediment sampler and Lidar (light detection and ranging) range finder to determine the spatial variability of stratigraphy and sedimentology of what in the past has been generally referred to as meandering river point bar deposits.

In the Chehalis tidal river estuary, we recognize three different lithostratigraphic styles of point bar deposits that consist of the following: 1. the good, 'clean' gravel and sand (no mud beds) with net sand/gravel percentage to gross stratigraphy (100% N/G) in proximal-most point bar deposits, 2. the potential, where sand-dominated IHS deposits (> 50% N/G) form in the mid point bar reach, and 3. the ugly, downriver from the channel curvature inflection point, mud-dominated IHS deposits (< 50% N/G) deposit from about mid point bar to the distal-most location, with mud beds thickening distally.

The spatial and stratigraphic variability of sedimentology in the McMurray Oil Sands, particularly within Steam Assisted Gravity Drainage (SAGD) operations, can be challenging and rewarding if one can avoid mud or mudstone IHS deposits, which could comprise as much as 70% of the total McMurray Formation (R. Strobl, Statoil, pers. comm., 2012). Clean sand reservoirs, 'the good', are those free of IHS deposits (sand/mud couplets), and are the preferred targets for SAGD 'The potential' lithofacies are those that contain sand-dominated IHS deposits in which mud interbeds can cause limited expansion of SAGD steam chambers. And, 'the ugly' are those mud-dominated IHS deposits (counter point bar deposits) that should be avoided.

The Good, Proximal-Most Clean Sand Point Bar Deposits

The proximal-most point bar deposits of clean sand (100% N/G) are the most preferred reservoirs for SAGD operations in the McMurray Oil Sands (R. Strobl, Statoil, pers. comm., 2012). On the basis of our research in the Chehalis River tidal estuary system, we suggest a 200 m long reach along the channel of proximal-most point bar has no mud beds. From vibracores and drag sampling of channel bottom sediment, we suggest that additional coarse clean sediment (sand or gravel) extends beneath the uppermost 8 m of sandy IHS deposits. One of the channel cross sections indicated that once below the intertidal zone, clean coarse sediments extended to a depth of 25.5 m below bankfull, and moreover, extended laterally 450 m beneath the sandy IHS point bar complex. From this example, a simple conclusion would suggest that these subtidal point bar deposits should extend down-valley considerable distances, perhaps for 1000s of meters within a given point bar deposit.

In the nearby Willapa River, another but smaller tidally-influenced estuary, located 30 km south of the Chehalis, is a similar lithofacies assemblage of point bar deposits. In the Willapa, proximal-most clean sand point bar deposit is missing. However, both sand dominant IHS point bar and mud dominant IHS counter point bar deposits are present. While the Willapa carries about 25% of the flow discharge as does the Chehalis, it still follows the trend of downvalley meander migration and down channel fining of sediment grain size.

The Bad, Sandy IHS Point Bar Deposits

We classify sand dominant IHS that contain thin mud interbeds as 'potential reservoirs' because mud beds within the vertical profile will inhibit the movement and growth of SAGD steam chambers in the McMurray, particularly in the upper section of point bar deposits. From vibracores in the Willapa River this pattern is particularly common. However, in the Chehalis, the pattern of coarse sediment beneath the subtidal and slightly deeper there exists a zone of clean sand and gravel, more characteristic of proximal point bar sediment. Though mud interbeds of the sand/mud couplets can eventually yield to steam pressure, it is thought that breaking through multiple mud beds may take to long to be economic.

While sand dominant IHS reservoirs are difficult for bitumen recovery, the ugly downside of mud dominant IHS reservoir (counter point bar deposits) represent a geologists worst nightmare—mostly money spent on heat energy and water for steam resulting in limited bitumen recovery.

The Ugly, Muddy IHS Counter Point Bar Deposits

Counter point bar deposits of mud-dominated IHS (< 50% N/G) form directly downriver from point bars of sand-dominated IHS, or approximately downriver from the channel curvature inflection point. These deposits occur most extensively in low gradient meanders (10-4 cm/km) in mixed load rivers that migrate down-valley, rather than towards valley sides (lateral expansion) as in steeper channel reaches. Counter point bars form opposite curvatures (arcing up-valley) to those in point bars that arc down-valley. If one is looking down-valley from above, point bars form as convex arcs and counter point bars form concave arcs. In modern river estuaries each can be distinguished by surface scroll bar and vegetation patterns on the floodplain. As a ‘rule of thumb’ the transition from point bar to counter point bar usually occurs at about the inflection point or crossover of channel curvature. In ancient river estuary deposits (eg McMurray), seismic time slices show similar arcing patterns, except they represent sediment density changes of sand and mud beds. Seismic time slice patterns mimic scroll bar patterns, and thus, can be used to infer lithostratigraphic trends and thus help direct drilling strategies.

The lateral extent of counter point bar lithofacies can occur over considerable distances downvalley. While point bar IHS stratigraphy, dominated by relatively clean sand, is generally well understood, mud-dominated (< 50% N/G) counter point bar stratigraphy and its lateral extent is not well understood by most geologists. Depending on the size of an active or ancient river system, lateral continuity of counter point bars and associated deposits can extend for 100s of meters across a valley and 1000s of meters down-valley.

Summary

The significance of not understanding the subsurface lithostratigraphy and subtle lateral facies transitions from proximal clean sand and/or gravel, to sandy IHS point bar, to mud dominant IHS counter point bar in ancient tidal-influenced fluvial meander rocks could result in unexpected, underperforming hydrocarbon reservoirs, particularly in thermal recovery operations in the Alberta Oil Sands and other light crude meander-deposited reservoirs. In meandering river tidal-influenced deposits, if N/G is > 50%, they are generally thought to be sand-dominated IHS point bar in origin, whereas meander strata with <50% N/G (mud-dominated) should be regarded as counter point bar in origin and be seriously reevaluated or avoided. The ‘good news’ is that recent sophisticated seismic-reflection-time slice data now allows for such detailed imaging of some subsurface reservoirs that can map the aerial extent of counter point bar and point bar deposits and thus better predict lithofacies quality.

We believe the modern Chehalis and nearby Willapa river tidal estuaries in SW Washington State are the most accessible and the most similar modern analogues to the Middle McMurray Oil Sands. Further, we recommend that this point bar-lithofacies association proposed here be tested against McMurray field data (seismic time slices, logs and core) from different the Oil Sand SAGD prospects, particularly if seismic time slice maps are available.