Point Bar Modeling, Middle McMurray Formation, Alberta

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Abstract

The Lower Cretaceous McMurray Formation contains one of the most important hydrocarbon accumulations in the world. The McMurray Formation is characterized by highly heterogeneous strata that have been attributed to fluvial, estuarine and/or deltaic depositional settings (Flach and Mossop, 1985; Crerar and Arnott, 2007). In-situ development of the deposit is largely accomplished through steam assisted gravity drainage (SAGD). Understanding the distribution of the resource within this heterogeneous setting is paramount for a successful development program utilizing this technology. In essence, SAGD development requires particularly high-resolution sedimentological and geochemical interpretation. The objective of this project is to create realistic, geologically sound, reservoir models that can be used for simulation.

The McMurray Formation is a heterogeneous amalgamation of a variety of sedimentological elements (Figure 1). High-quality three-dimensional seismic reflection data reveal distinct geomorphologic features that are comparable to those of well-studied modern systems. Large-scale depositional elements recognized within the seismic reflection mosaic include point bars that evolved through lateral channel migration, point bars developed through downstream translation, counter point-bars, sandstone-filled channels, and abandoned channels or oxbows. Results of our efforts to model a point bar that evolved through lateral channel migration are presented here. Model building involves broad scale delineation of reservoir and non reservoir facies from geomorphological analysis followed by incorporation of finer scale data from core, petrophysical log, grain size, mineralogic and seismic analysis into the modeling software.

The initial point bar architecture was derived from a series of 30 high-quality seismic time slices (such as that shown in Figure 1) at 1 ms intervals. The 3-dimensional geometry of the abandoned channel fill was constructed by tracing this feature on successive time slices and then smoothing. This gives a bounding surface to the point bar deposits. Elements visible on the seismic time slices within the point bar can be approximated by a series of circular arcs. These arcs were followed through the time slices in 3 dimensions. Trends of the centers and radii of these arcs fit simple linear equations. These equations were used to construct a series of surfaces within the 3-dimensional point bar that we interpret to approximate depositional surfaces. These surfaces were used in the earth modeling.

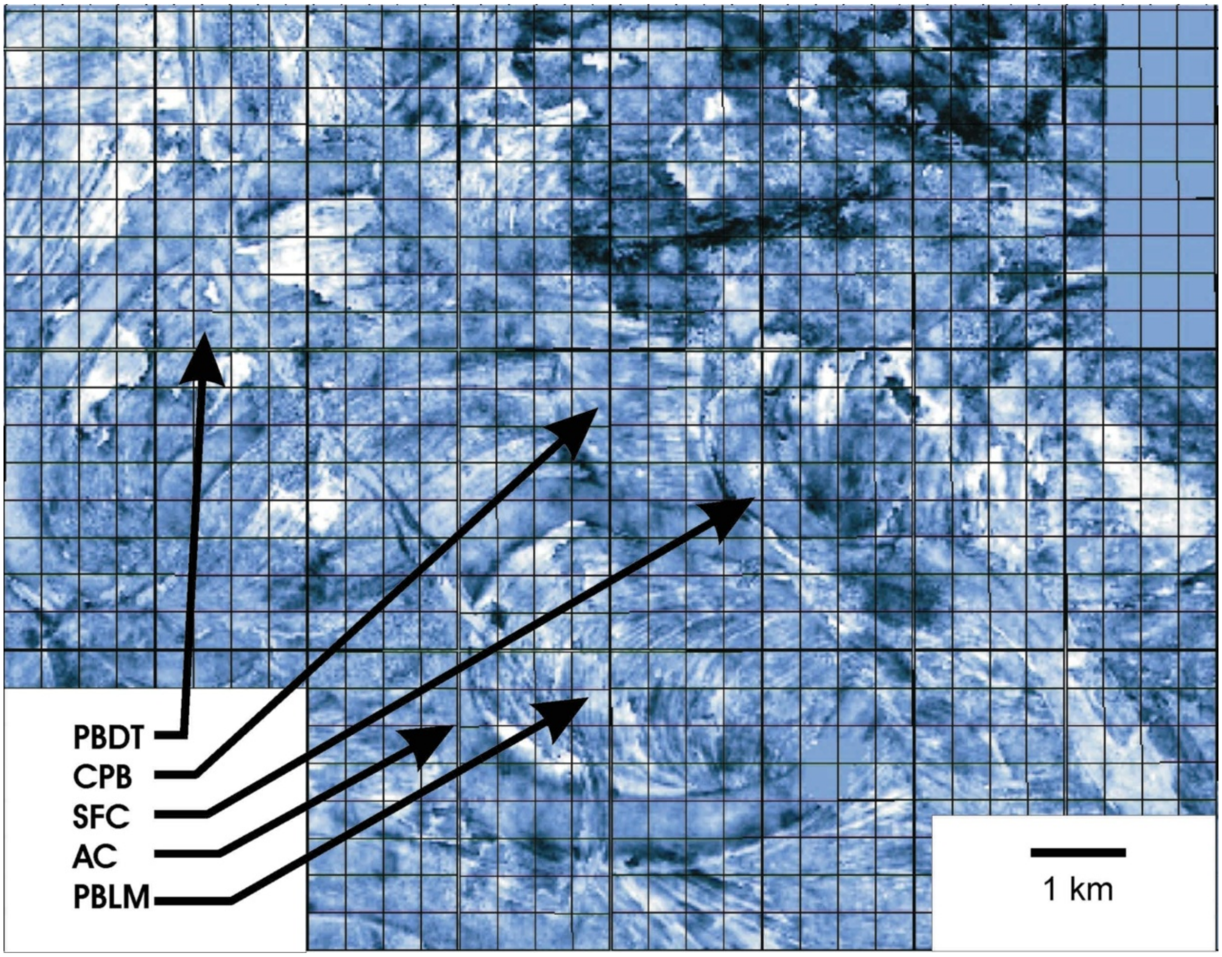

Figure 1. High-quality seismic reflection time slice. Labels indicate areas and elements being studied as part of the larger project (PBDT - point bar developed through downstream translation, CPB counter point-bar, SFC - sandstone-filled channels, and AC - abandoned channels or oxbows.). The focus of this paper is on PBLM - a point bar that evolved through lateral channel migration and associated deposits such as the abandoned channel fill that bounds it.

Today's computer technology allows three dimensional viewing of the point bar architecture and the incorporation of well and core data into the model. Dip meter data from wells that penetrate the point bar deposits were used to confirm, and if needed, to adjust, the slopes of the depositional surfaces. The overall fit of these data give us some degree of confidence in the point bar architecture constructed in the model.

All available core through the point bar was examined. Sediments consist of sandstones and siltstones; most sandstones within the point bar are saturated with bitumen whereas siltstones are not. Facies were assigned based on the sand/silt content and sedimentary structures (physical and biogenic) present. Core observations were used to construct “facies logs” in the earth model (Figure 2). The “facies logs” in wells where core was not available were constructed by comparison of petrophysical log signatures with those from cored wells.

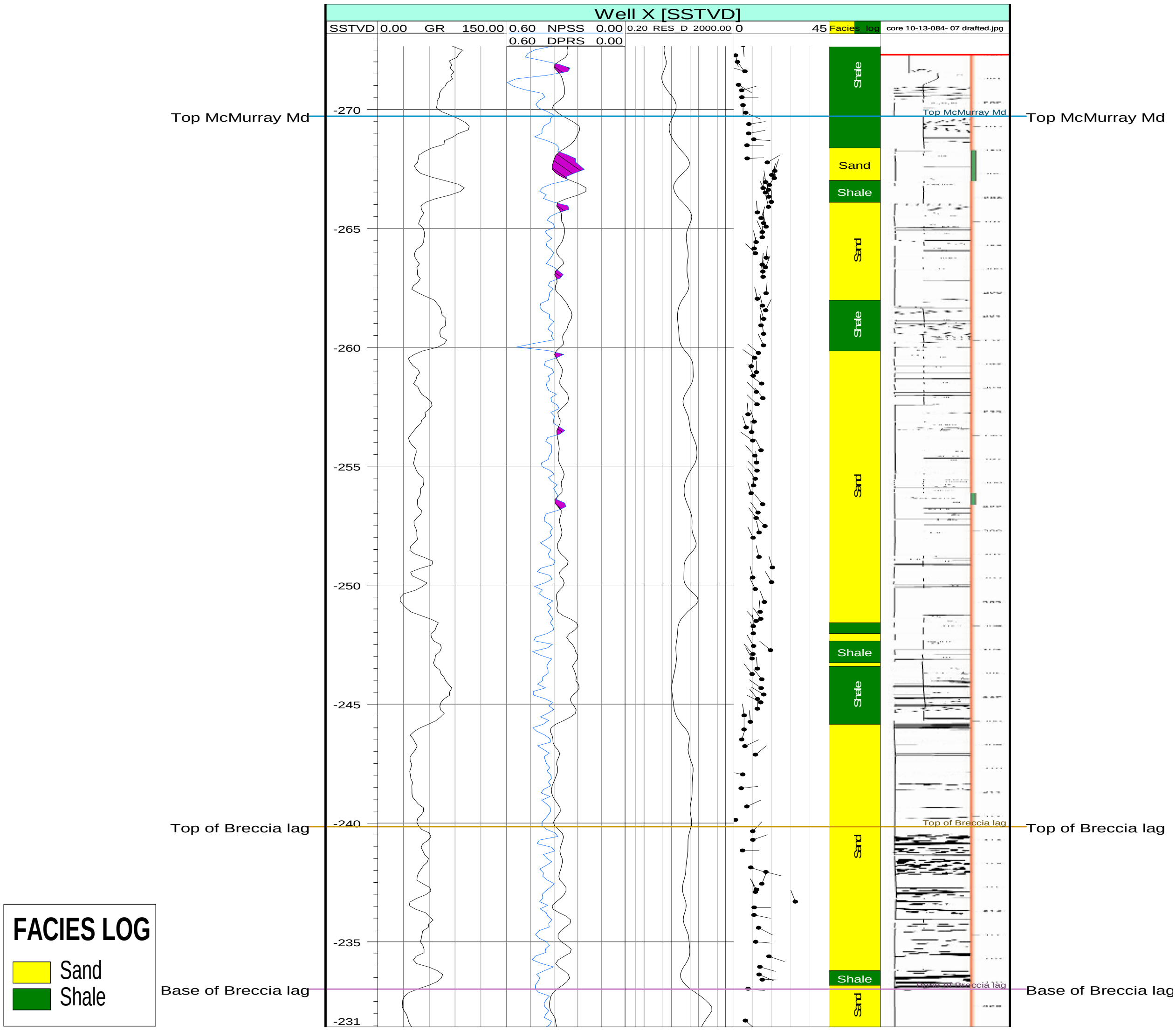

Figure 2. Display of wireline logs used to delineate stratigraphic tops. From left to right, gamma ray, neutron-density porosity, deep resistivity, dipmeter, facies log and core description.

Facies logs were then used to populate a 3-dimensional facies model, with mapped surfaces constraining interpreted genetically-related depositional volumes (Figure 3). Facies are allowed to change smoothly and systematically within the depositional volumes that are bounded by these surfaces; however they may change abruptly across these depositional surfaces. This 3-dimensional depositional model is then populated with the rock and fluid properties in order to create a 3-dimensional reservoir model.

Bitumen abundance and quality are also being assessed in order to characterize the fluids in the area. The detailed molecular geochemistry of core extracted bitumen is used to characterize the variation of the oil chemistry in detail and thus gives an indication of the controls on the variation of fluid properties. These data help to define the extent of segmentation or compartmentalization of reservoir elements even when pressure and/or geologic data are ambiguous. Understanding reservoir continuity is critical to optimizing field-development planning. Identification of reservoir segmentation is also important to the efficient placement of injector/producer pairs when pressure maintenance by steam injection is planned.

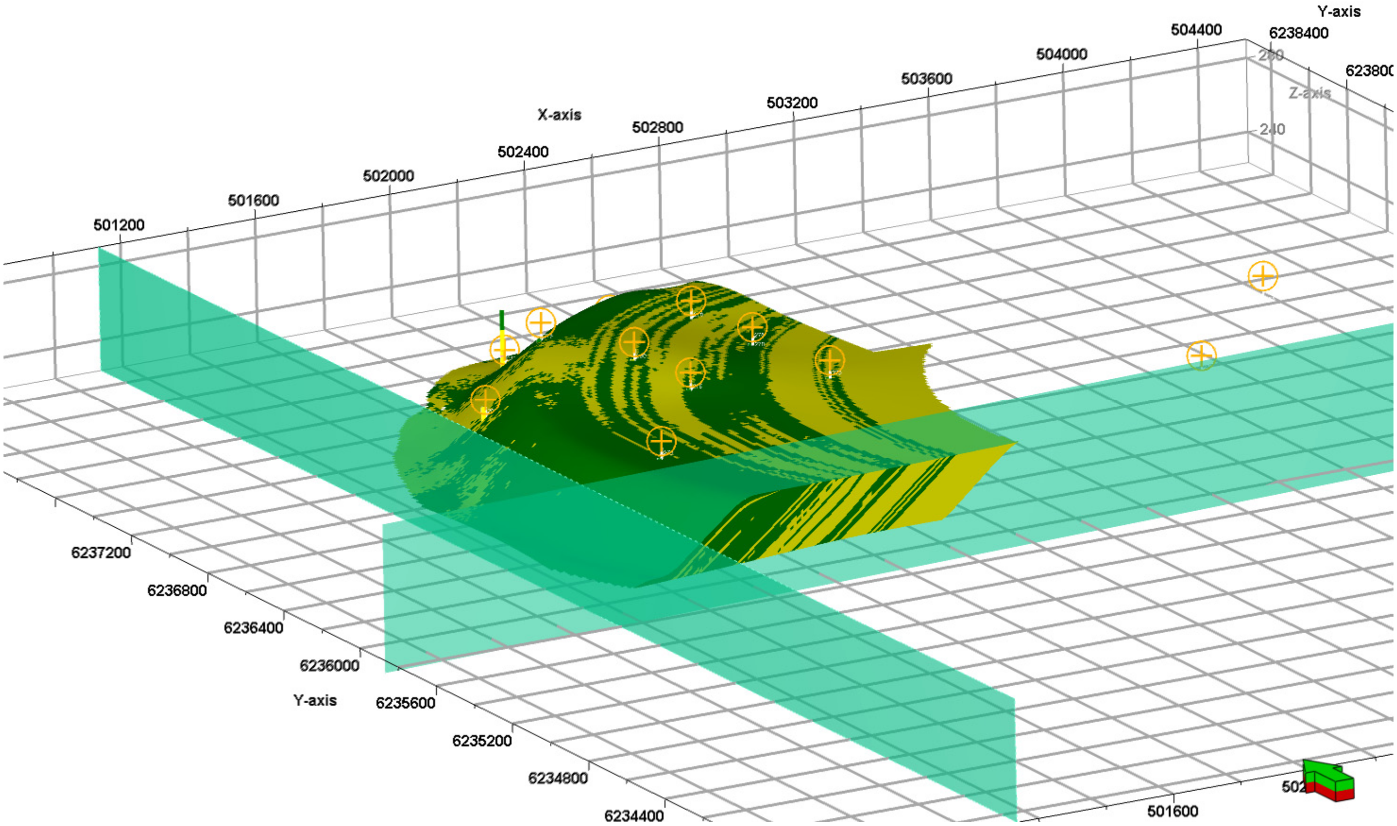

Figure 3. Three dimensional view of point bar architecture built by lateral channel migration modeled. Depositional surfaces and volumes are curved in three dimensions. Reservoir properties change systematically along these depositional surfaces. Vertical exaggeration is 5x.

Solvent extracted bitumen was analyzed for its total hydrocarbon compositions with GC-MS (Gas Chromatography-Mass Spectroscopy). Weight percent bitumen and SARA (saturates, aromatics, resins, asphaltenes) analyses were performed via TLC-FID (Thin Layer Chromatography-Flame Ionization Detection). Oil geochemistry can be used in several very different ways to help predict lateral and vertical variations reservoirs and in oil quality in a reservoir. Estimation of oil properties such as viscosity was performed by using a calibrated transform function to convert the geochemical analyses of the core extracts into viscosity values. This information is incorporated into the reservoir models and can be equally as important as the rock properties in reservoir performance.

References

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