From township to well pad: A geological approach to geomodeling McMurray Formation channel-belt deposits

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Summary

In order to build accurate and realistic geomodels at the well pad scale, it is imperative to understand and integrate with the geology at the township scale. However, township-scale models are rarely constructed due to the amount of data, computing power, and time required to map stratigraphic surfaces and lithologic properties over such large areas. In this study, we present a township-scale geomodel of McMurray Formation channel-belt deposits that informs and integrates with pad-scale reservoir models. A 130 km^2 geomodel constrained by 3D seismic data and 350 boreholes characterizes point bar, counter-point bar, mid-channel bar, side-attached bar, and abandoned channel deposits of the A2 valley in the McMurray Formation (Fig 1). The model has a grid cell size of 5 m x 5 m x 20 m and it is populated with a vShale (Shale Volume Ratio) property derived from gamma-ray logs, which is used as an inverse proxy for sandstone distribution (Fig. 1C-E). Results show trends of decreasing reservoir quality as point bars evolve, and high-quality reservoir adjacent to and beneath abandoned channels in side-attached bar deposits. Township-scale models allow for first order identification of potential future development areas. To evaluate those future development areas, a focused 6-section area of the model is re-gridded at 1 m x 1m x 10 m, and populated with facies, vShale, porosity, permeability, and fluid saturation from approximately 40 boreholes. We utilize a new approach to grid cell orientation that follows internal dipping surfaces, as opposed to traditional horizontal grid models. The internal stratigraphic architecture of the A2 valley deposits is consistent with the township-scale model. We further constrain deposits older than the A2 valley that are not well-imaged in 3D seismic by detailed well correlation of wireline log, core, and dipmeter data. We test the impact of internal stratigraphic architecture on steam chamber development and demonstrate the impact of stacked channel-belt units and dipping beds on the conformance of steam. The results presented here can be applied to other stacked channel-belt deposit reservoirs in the McMurray Formation and other oil sands properties.

Introduction

With increasing quality and density of subsurface data sets, it is possible to construct geologically realistic and accurate geomodels that capture internal stratigraphic architecture and facies transitions. However, this information is often lost in the up-scaling process and its impact on simulation and production are unquantified. Reservoir models that honour and preserve the geology will better inform reservoir characteristics and provide realistic production simulation (e.g., Strobl et al., 2013; Su et al., 2017). In the Cretaceous McMurray Formation, Steam-Assisted Gravity Drainage recovers bitumen from channel-belt deposits (Strobl et al., 1997; Gotawala and Gates, 2010). The high-quality 3D seismic data and dense borehole spacing at Surmont provides an ideal location to construct a township-scale model of channel-belt deposits that integrates with SAGD pad-scale reservoir models (Fig. 1). Upper channel-belt deposits are well-constrained and imaged in 3D seismic data (Fig. 1A; e.g., Durkin et al., 2017), however lower units are less-constrained and their characterization relies heavily on detailed well-log correlation and stratigraphic dip analysis (e.g., Fustic, 2007). Our objective is to capture the internal architecture of stacked channel-belt deposits and asses their impact on steam chamber development.

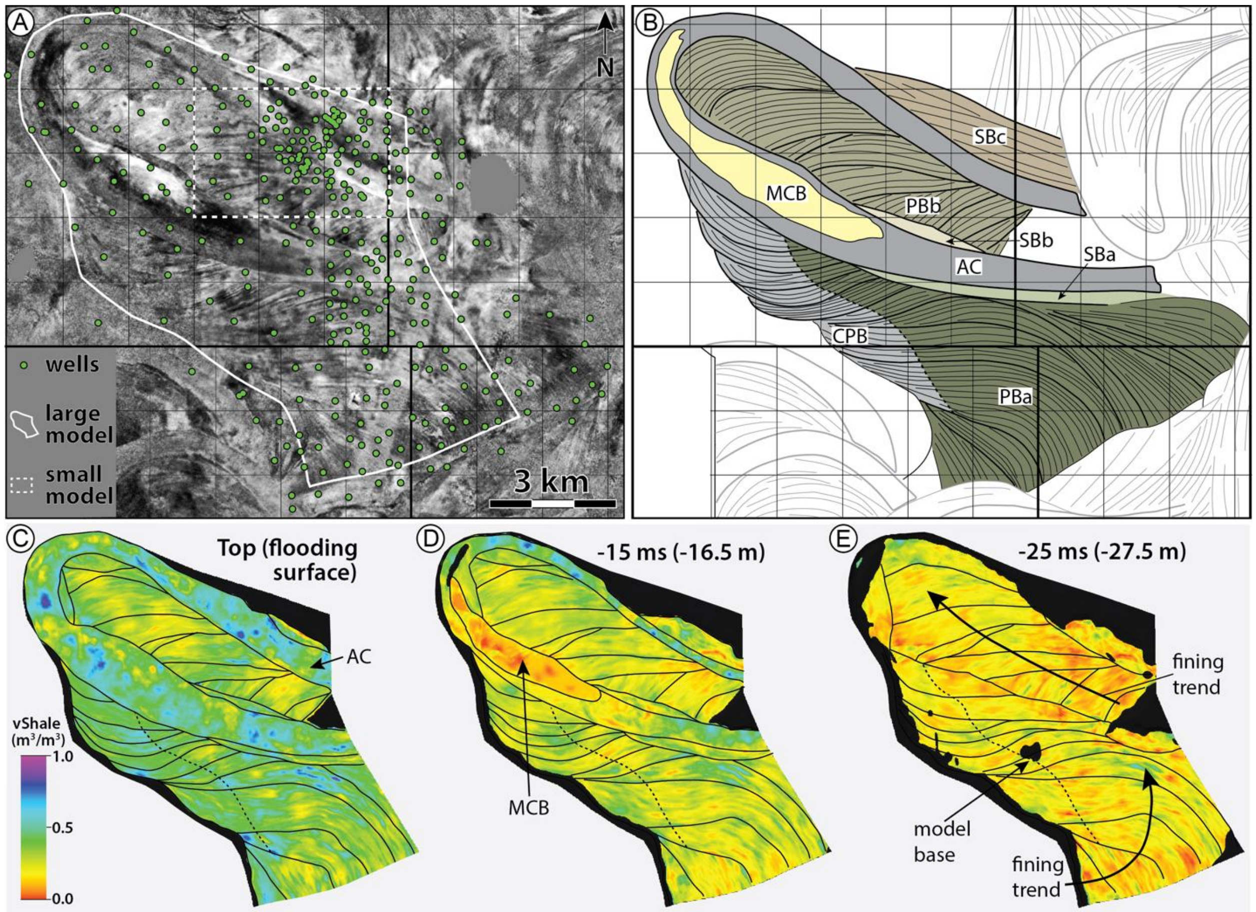

Figure 1: McMurray Formation study area at Surmont. A) 3D seismic amplitude stratal slice from near the top of the reservoir. Distribution of boreholes (green) and extent of township-scale (large) and well-pad scale (small) models are shown. B) Channel-belt elements identified in seismic geomorphology, which form the basis for the zones of the large model. C) - E) Series of maps through the vShale property model from the top McMurray Fm. surface C) to near the base of the channel belt E). Note the low vShale values in the mid-channel bar (MCB) and increasing vShale values from older to younger point bar deposits (fining trend). AC – abandoned channel.

Methods

To construct the township-scale geomodel, stratigraphic surfaces were mapped in 350 boreholes and throughout the 3D seismic survey. Seismic geomorphology identified several channel-belt elements including point bar (PBa, PBb) and counter-point bar (CPB), mid-channel bar (MCB), side-attached bar (SBa, SBb, SBc), and abandoned channel (AC) deposits (Fig. 1B). These elements form the zones of the geomodel, which are then layered according to their internal architecture. Grid cells are oriented parallel to bedding (dipping surfaces) with a cell size of 5 m x 5 m x 20 m. Cells are populated with an up-scaled vShale property derived from gamma-ray well logs (Fig. 1C-E). For the small-scale model, existing architecture for upper channel-belt deposits is extracted from the township-scale model and re-gridded to 1 m x 1 m x 10 m. Additional well-log correlation and stratigraphic dip analysis constrained and integrated lower channel belt elements, for which zones were created and layered according to dip-meter logs. The small model was populated with facies, vShale, porosity, permeability, and fluid saturation. Several iterations of steam chamber simulation were run for individual well pairs and pads.

Results and Conclusions

A 130 km^2 geomodel of upper channel-belt deposits characterizes vShale distribution for point bar, counter-point bar, mid-channel bar, side-attached bar, and abandoned channel deposits. Results inform the distribution of reservoir quality, including decreasing reservoir quality as point bars evolve, and high-quality reservoir in mid-channel and side-attached bar deposits. The township-scale model also identifies potential areas for future development.

A 15 km^2 subsection of the large model is selected for further analysis. Lower channel-belt mapping reveals variable preservation of point bar deposits up to 25 m thick locally, and thick sandstone-dominated successions. Evidence for mudstone and IHS-dominated successions are also present. A geomodel is constructed for this subsection that utilizes zones from the township model and incorporates newly constructed zones from lower channel-belt mapping. Results reveal complex stratigraphic architecture in stacked channel-belt deposits and variability in connectivity across basal erosional surfaces.

We run a series of steam chamber simulations to assess the impact of bed-oriented grid cells, internal stratigraphic architecture, and stacked channel-belt deposits on steam chamber development. Results indicate that steam chamber growth is controlled by dipping accretion surfaces and inhibited where IHS-dominated point bar deposits separate lower and upper channel-belt deposits. These results build on and further refine our understanding of steam-chamber growth in deposits of the McMurray Formation (Su et al., 2013; 2014).

Overall, we demonstrate a methodology for township to well-pad scale geomodeling that incorporates detailed stratigraphic architecture with bedding-parallel grid cells. Our novel approach to characterizing lower channel-belt deposits demonstrates the feasibility to incorporate stratigraphic architecture in poorly-constrained zones. The results presented here are applicable to geomodeling of channel-belt deposits in the oil sands and globally.

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