Implications of Stacked Meander-belt Deposits for Steam Assisted Gravity Drainage, McMurray Formation, Alberta

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Summary

Integration of well logs and core data of the McMurray Formation suggest vertically stacked meander-belt deposits, many of which will have major implications for reservoir development. The best preserved, youngest meander-belt is well imaged using seismic data and therefore reservoir models are constructed much easier than older meander-belts that are often overlooked due to lack of lithologic contrast and resolution in seismic data. Core description and stratigraphic dip analysis are vital in differentiating between point bar deposits. Horizontal SAGD well performance is impacted by the the stratigraphic architecture within the reservoir zone. Steam chamber growth is uninhibited where stacked meander-belt deposists have a sand-on-sand contact and production rates are typically higher. Heterogeneities caused by the evolution of a meander-belt already present many challenges for development of reservoirs, and this complexity increases when vertically stacked belts are considered. Startigraphic mapping of underlying deposits is vital for successful well pair placement and production. Predictions of the multiphase fluid flow in the reservoir and the behaviour of rising steam chamber are far more accurate when the detailed geology of the meandering channel belt deposits are considered in dynamic model construction.

Introduction

The Lower Cretaceous McMurray Formation is part of the Athabasca Oil Sands Region of northeastern Alberta. Primary hydrocarbon-bearing units of the McMurray Formation are primarily found within point bar deposits of the Middle McMurray Formation (Carrigy, 1959). The process of point bar development and the resulting rock record has been studied thoroughly. Additional fluvial processes related to meander-belt evolution such as intra-point bar erosion, counter point bar formation and channel abandonment contribute to heterogeneities within these deposits that have a major impact on reservoir connectivity (Jackson, 1976; Thomas et al., 1987; Smith et al., 2009; Willis & Tang, 2010; Hubbard et al., 2011; Durkin et al., 2015). Steam assisted gravity drainage (SAGD) is one of the main technologies used to produce highly viscous bitumen from these deposits. Optimal production and therefore placement of the injector and producer well pair relies heavily on the internal architecture of the reservoir (Butler and Stephens, 1981). The youngest, best preserved meander-belts of the McMurray Formation have been extensively studied using 3D seismic data, well logs and core (Hubbard et al., 2011; Su et al., 2013; 2014; Durkin et al., 2017). However, underlying deposits are often overlooked because they are not well imaged with seismic data. Geological models that incorporate the underlying units often do not consider the geology at the same level of detail as meander-belts that are imaged with seismic. For example, Su et al. (2013; 2014) refer to the underlying units as remnant channel successions, with no emphasis on the specific architecture. Often horizontal

SAGD well pairs are placed in this lower interval and characterization of vertically stacked meander-belt deposits is therefore vital for reservoir development.

Methods

This study aims to enhance current reservoir models of the McMurray Formation by using a vast dataset of well logs and numerous core descriptions over an area of approximately 400 km^2. The youngest and best preserved meander-belt is well imaged by seismic data and is used to model architectural elements and sedimentological heterogeneities of the point bar deposit (Durkin et al. 2017). Different depositional elements are constructed as a separate zones and each zone is then internally populated for the geobodies. Previous point bar models constructed by Durkin et al. (2017), Su et al. (2013) and others focus only on the youngest point bar within a given meander-belt. However, drilled SAGD well pairs in the study area are often placed beneath the well constrained deposits. In order to map these lower, older meander-belts that are not well-imaged with seismic, core descriptions and stratigraphic dip analysis are used (Fustic, 2007). Incision by the overlying meander-belt makes correlations difficult and adds to the complexity of reservoir characterization when vertically stacked meander-belts are considered. Heterogeneities in the reservoir zones that can be attributed to meander-belt evolution are included in the dynamic model. Publically available, historical production data from operating SAGD pads in the study area are further implemented to tune the geological parameters of the reservoir model and improve the predictive capability of the modeling.

Results and Conclusions

The youngest, seismically constrained meander belt in the study area is up to 50 m thick and shows evidence of intra-point bar erosion and rotation, counter point bar formation and channel abandonment. Several cores within the study area have been described to confirm the uppermost meander-belt base and to aid in mapping the older, underlying deposits. Core, well log and dipmeter analysis reveal local preservation of complete point bar successions up to 25 m thick in some regions, while multiple incomplete successions are preserved in other areas. In places, the mudstone and inclined heterolithic strata (IHS) of older, underlying point bar successions have been completely removed by the overlying meander-belt and thick amalgamated sands are present. These poorer quality layers remain in areas where the younger belts did not remove them entirely. There is also evidence for point bar and counter point bar formation in the underlying deposits (Figure 1; Durkin et al. 2018). A series of average gamma ray “slices” and net sand maps at 3 m intervals from the base of the youngest meander belt and suggest some of the horizontal well pairs have been drilled in low quality reservoir zones. Reduced cumulative oil production volumes and rates in specific well pairs may be attributed to remaining mud and IHS barriers between point bar succesions in areas where thick reservoir sands are not apparent in the underlying interval. Production rates are predictably low in areas where the underlying net to gross is extremely low. Contrasting IHS dip directions between the uppermost meander belt and the underlying deposits may also be considered to explain lower production as the growth of the steam chamber will become convoluted and limited. Furthermore, mudstone barriers and reservoir heterogeneities affect the steam chamber confromance along horizontal SAGD well pairs and lower the production efficiency (Su et al., 2013). The analysis demonstrates the impact of meander-belt-scale heterogeneity on reservoir connectivity and performance, with implications for global fluvial reservoirs.

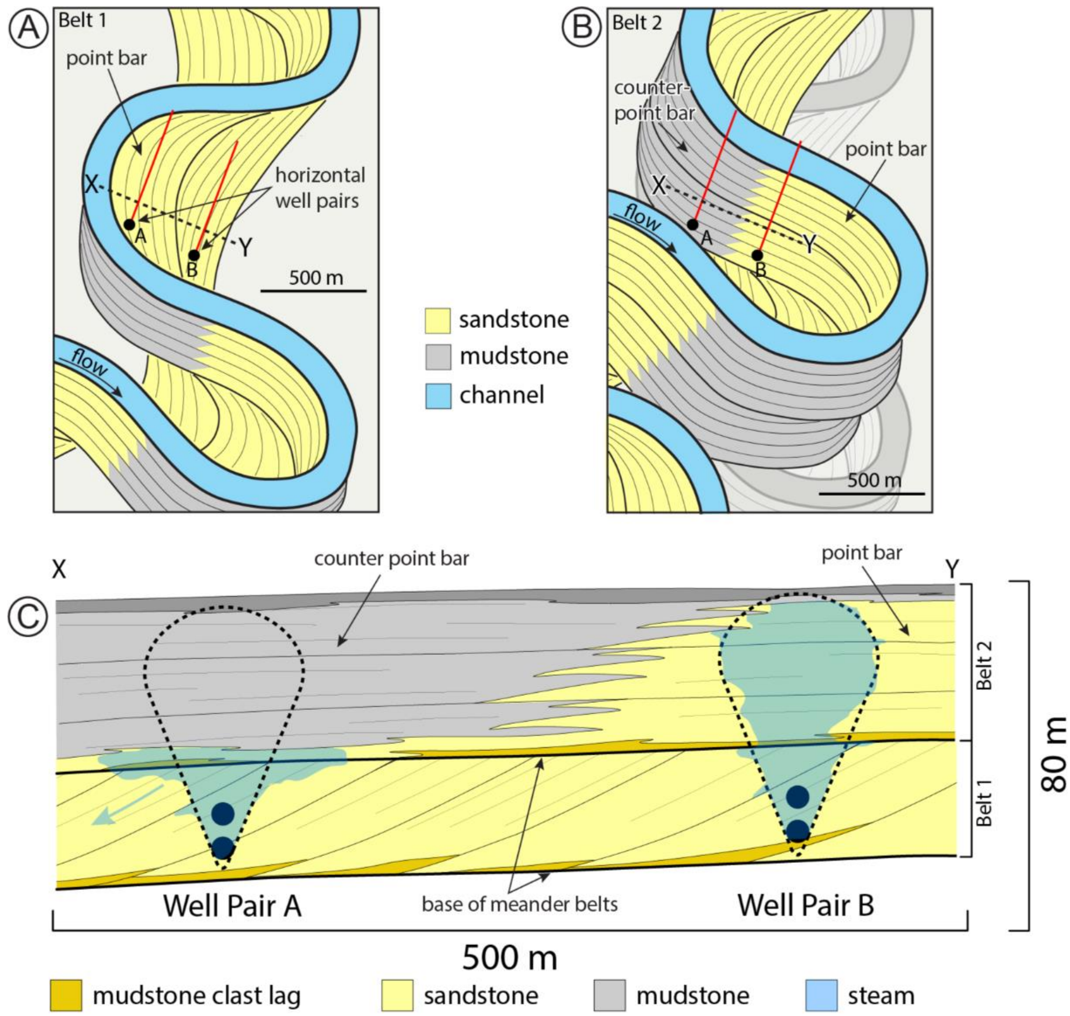

Figure 1. Two horizontal well pairs placed in hypothetical, stacked meander-belt deposits of the McMurray Formation. The meander-belt from (B) is stacked on top of the deposit in (A). (C) Cross section demonstrating the affect of stacked meander-belts on steam chamber development from SAGD horizontal well pairs. In well pair A, a counter-point bar deposit from (B) is stacked on top of meander belt (A) and the steam chamber's growth is hindered. Where two sandy meander-belts are stacked, as in well pair B, the steam chamber can fully develop (Durkin et al., 2018).

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