Depositional Architecture of the middle McMurray Formation: Suncor Firebag SAGD Asset

Heather A. Gray
Suncor Energy Inc. Calgary, Alberta, Canada

Summary

The Firebag asset is the largest in situ oil sands project in the Suncor Energy Inc. (Suncor) portfolio. The project produces more than 200 kbpd of bitumen through thermal Steam-Assisted Gravity Drainage (SAGD), in the Lower Cretaceous McMurray Formation and since 2003 has produced more than 500 MMbbls of bitumen.

In SAGD developments, steam chamber growth is largely affected by reservoir properties and connectivity. These have a great impact on production rates and recovery factor that influence the forecasting of emulsion production, steam availability and timing of future pad development. The main production is from the reservoir in the Firebag Basin that contains a thick accumulation of lower McMurray fluvial deposits. As Suncor steps out to further develop pads at Firebag, the stacked middle McMurray (mM) reservoir, a large scale fluvial-estuarine point bar system, will become ever more important. The aim of the project was to fundamentally understand the depositional framework of the mM to provide insights into optimal extraction.

Introduction

The Firebag asset is situated in the Firebag tributary east of the main trunk McMurray channel fairway. The McMurray Formation at Firebag is informally divided into lower, middle and upper units, representing a transgressive package. The lower McMurray is further divided into three units: lower McMurray 1, 2 and 3. The main reservoir currently exploited at Firebag is the lower McMurray 3 (lM3), a braided fluvial system and the middle McMurray, a fluvial-estuarine point bar system.

The Firebag Basin was formed due to karsting and solution collapse prior to McMurray deposition (Altosaar, 2016). This depression provided accommodation for the high energy lM3 braided fluvial system, and subsequent deposition that filled the basin with a thick 20-30 m accumulation with thinner deposits on the paleo highs outside of the basin. The mM fluvial-estuarine point bar deposition followed, with a general uniform thickness across the area ~30-40 m thick, suggesting no further large scale tectonic activation of the basin.

The first stages of development at Firebag have centered upon the stacked systems in the Firebag Basin, with the producer and injector pairs placed in thick accumulations of lM3 deposits. In future developments outside of the Firebag Basin, the mM will play an increasingly important role and will in some cases be the target of producer / injector pairs. Overall bitumen recovery at Firebag in mature pads is exceeding expectations, possibly suggesting a greater contribution from the mM than previously forecasted. As a result, the depositional architecture of the mM has become progressively important to understanding reservoir connectivity and accessibility for future development timing.

Methods and Results

In this study, over 1000 wells were analyzed with the basic log suite, including 705 with core, 535 with image or dip meter logs, and 270 with particle size distribution (PSD) data. A 10 km x 14 km seismic 3D merge survey was interpreted including spectral decomposition and optical stacking to outline the architectural elements of the mM. The basal and top picks of the architectural elements were selected in wells, and projected onto seismic for 3D mapping. In a sand rich environment, the contact between the lM3 and mM is not easily observed in core or on seismic, however, with PSD and image logs, a suitable pick can be made.

The mM at Firebag is characterized by a series of point bars and associated abandoned channels. The environment was highly erosive, consisting of partially cannibalized mM point bars in a single meander belt, and as a result stacked point bars are uncommon. This is evident in the image logs and seismic data. The abandoned channels typically range between 280-580 m wide and are 27-35 m thick. Point bar dimensions are more difficult to measure at Firebag due to low preservation. However, two nearly complete preserved point bars are visible in seismic; an elongated point bar with a width, length and thickness respectively 1825 m, 4800 m, 35-40 m, and a second point bar with dimensions of 4000 m, 4500 m, 27-35 m. Flow direction was primarily towards the north. On the western part of the production area, point bar migration is largely to the north, while the central and eastern part of the production area has east/west point bar migration.

Conclusions and Future Applications

In the mature production area, 4D seismic does not highlight reservoir compartmentalization resulting from lateral accretion surfaces in the mM. The producer and injector wells are placed in the lM3 but steam has been able to migrate and infiltrate the entire reservoir zone. However, in areas with thinner lM3, the injectors are at the top of the lM3 or in the mM and early evidence for compartmentalization or higher permeability reservoirs is visible (Figure 1).

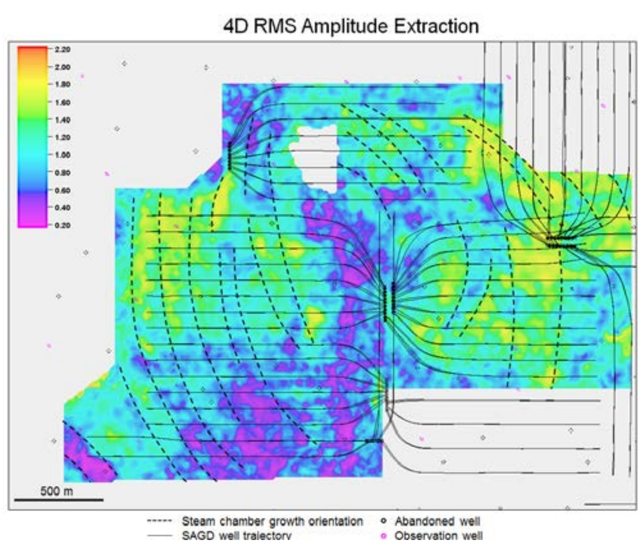

Figure 1: 4D RMS amplitude extraction representing the steam chamber. Steam is seen to preferentially migrate along the lateral accretion surfaces of the mM point bars.

Understanding the depositional architecture of the mM has great potential to improve the efficiency and economics of thermal recovery development such as SAGD. In particular this is very important for reservoir characterization and development efforts to minimize the impact of geological impairments such as mudstones, top gas and bottom water or lean zones. Suncor has implemented this work into the design and monitoring of its gas injection. Based on the monitoring results, the extent of gas zone aligned with the initial reservoir modeling predictions that was based on this geological model. This work also helps better placement of future observation wells for monitoring safety and progress of steam/gas injection zone. In order to optimize the performance of the recovery method the optimum number of observation wells can be located in ideal places with respect to the geological architect of mM.

To improve forecasting, the architectural element surfaces can be added to geomodels that can be up-scaled for simulations. Simulations can play a large role in forecasting new pad production, and understanding steam chamber growth within the mM zone in the current production area will help provide suitable analogue pads for future developments. A fundamental break down of depositional units enables better forecasting and bitumen extraction in a SAGD environment.

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References

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