GeoConvention
Calgary • Canada • March 7-11 2016
OPTIMIZING RESOURCES

Geochemical Insights into Reservoir Characterization: Integration of Geochemistry, 4D Seismic and Observation Well Temperature Data in a Producing SAGD Operation

Sabita A. Makoon-Singh, Todd L. Mazurkewich, Rudy S. Strobl, Dominique C. Holy, Devika J. Naidu, Dany C. Cadiou, David Gray, Sergio A. Merchan

Nexen Energy ULC

Summary

The estimation of steam chamber rise over the production life of Steam Assisted Gravity Drainage (SAGD) well pairs is essential for prediction of peak production rates, recovery factors, and steam chamber conformance. Heterogeneities such as mudstone interbeds and mudstone-clast breccias within McMurray Formation oil sands reservoirs reduce permeability and commonly have a direct impact on SAGD production and performance. However, the lateral extent of these vertical permeability barriers can be variable and often unpredictable based on data from core and/or well log interpretation only. Geochemical analysis of bitumen samples from core obtained below, within and above these heterogeneous intervals is proving valuable for differentiating baffles and barriers.

This paper demonstrates how geochemical prediction of barriers and baffles is corroborated by 4D seismic anomalies and temperature readings from observation wells in a producing SAGD oil sands area with encouraging results. Results from the work done to date are encouraging, with estimation of barriers vs. baffles predicted with an 83% success rate.

Introduction

Geochemistry is a valuable tool in the reservoir characterization toolbox that is often overlooked in the SAGD production of McMurray oil sands. The complex depositional history of channel successions and variable preservation of tidally-influenced deposits within the McMurray Formation makes it challenging to determine whether a given heterogeneous interval is a barrier or baffle to steam chamber growth during SAGD operations. Barriers are defined as heterogeneous intervals that prevent steam chamber rise over the production life of the well pair, whereas baffles have shorter lateral extent and allow steam to advance over time to access upper bitumen intervals. Previous publications have demonstrated that biodegradation of bitumen results in changes of viscosity and geochemical biomarkers above and below barriers (e.g. Fustic et al., 2011, 2013; Adams, 2013; Sereda and James, 2014).

Method

Five gram samples of bitumen sands derived from fresh core provide diagnostic geochemical biomarkers such as naphthalenes and phenanthrenes. Discontinuities in these markers can be used to identify geochemical barriers and baffles. In a clean reservoir void of barriers a smooth biomarker concentration gradient is commonly observed (Figure 1, Well C). Laterally continuous mudstone-dominated intervals or mudstone-clast breccias which act as a vertical permeability barrier commonly demonstrate clear

discontinuities or step changes in the biomarker concentration gradient (Figure 1, Well A). Geochemical barriers are identified by a change in the biomarker gradient.

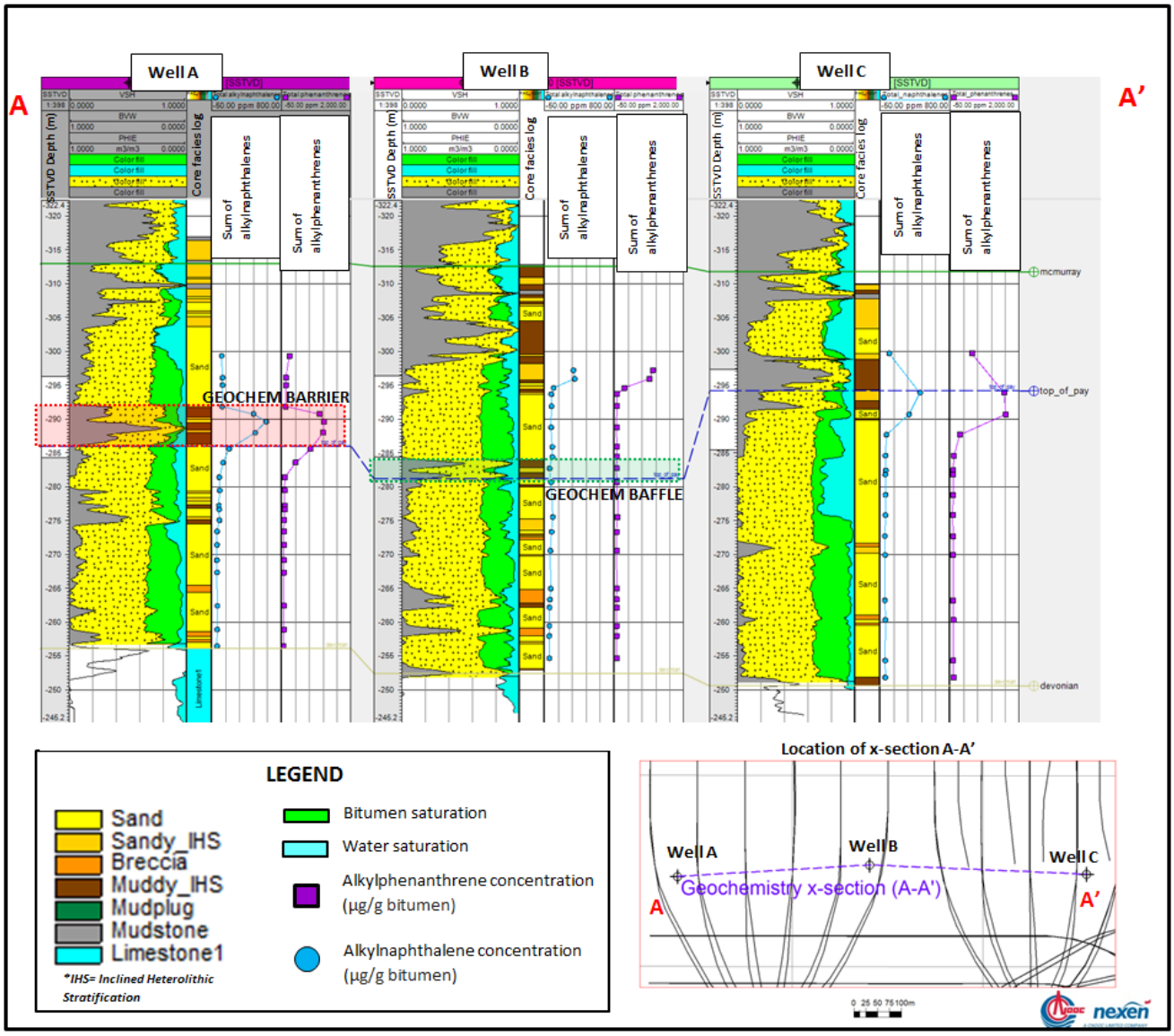

Figure 1. *W-E Structural/geological/geochemical cross-section (A-A') of the McMurray interval comparing normalized plots of alkylnaphthalenes/alkylphenanthrenes vs. depth to petrophysics and core facies log for three neighboring wells spanning across the heels of two operating SAGD pads.*

Examples

A case study of three wells is demonstrated in Figures 1 and 2. During the early life of the project, potential barriers and baffles were interpreted by utilizing data from well logs, core and 3D seismic (Figure 2A). As production proceeded, temperature data from nearby observation wells indicated impedance of steam chamber growth due to the presence of baffles or barriers in the reservoir. Over time, steam chamber development (>200°C) and a corresponding 4D anomaly was observed in the observation well, above what was interpreted as a baffle confirming the geochemical interpretation (Figure 2). The lateral extents, shape and height of 4D seismic anomalies provide a comprehensive visualization of steam chamber growth and associated controls on steam rise due to baffles and barriers.

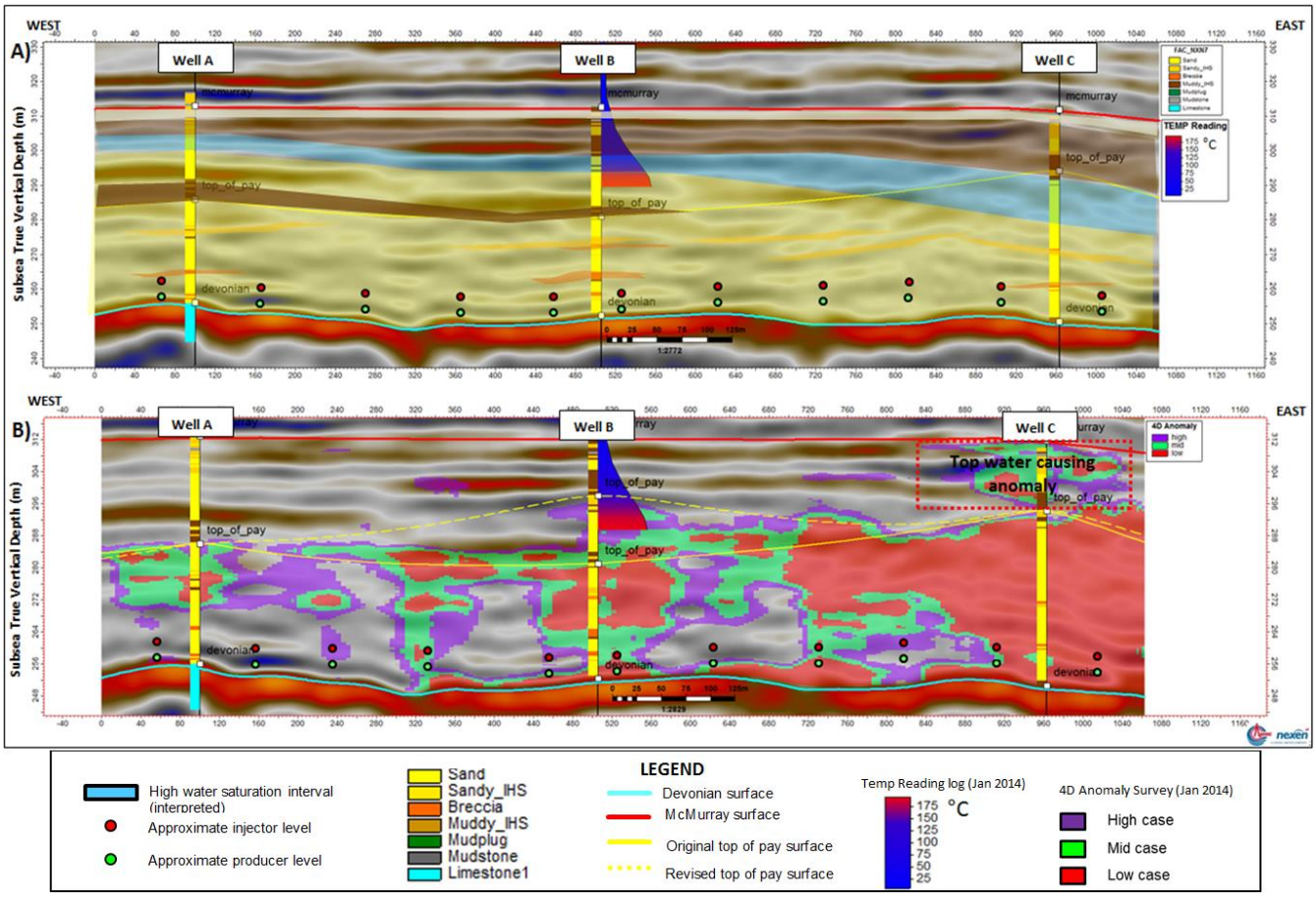

***Figure 2A**. 3D stacked seismic slice in depth overlain with generalized geological facies interpretations. This interpretation was made based on geological and geophysical data complimented by the geochemical and temperature data (Fig 1.). The thick muddy IHS package seen in the upper reservoir at well 'A' is interpreted to act as a barrier to steam. The package then thins towards Well B and pinches out somewhere between wells 'B' & 'C' (i.e. becomes a baffle). **Figure 2B.** 4D survey with low/mid/high case anomalies. The 4D anomalies appear to stop below the interval in well 'A' interpreted to be a barrier through geochemistry, whereas in well 'B' the anomalies seem to wrap around the interval interpreted to be a baffle using geochemistry. Temperature data also suggests that steam has advanced around the baffle in well 'B'.*

Conclusions

Baffles and barriers interpreted from geochemical analysis have demonstrated a good (83%) correlation to the steam chamber interpreted from temperatures in observation wells and 4D seismic. The benefit of geochemical measurements is availability prior to steam injection. This study shows that these measurements can be accurate predictors of barriers and baffles, especially when combined with other early project life data. Geochemical analysis is a valuable, simple and economical tool which has the ability to enhance reservoir characterization and prediction of SAGD well pair placement, production, and performance.

Acknowledgements

The authors wish to thank Nexen Energy ULC., a wholly-owned subsidiary of CNOOC Limited for permission to publish this data.

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