CSPG Canada's Energy Geoscientists
TOURMALINE OIL CORP.
CORECONFERENCE
16-17 May 2019 • AER Core Research Centre • Calgary, AB
Celebrating 50 Years

Low Resistivity Bitumen Pay, Pike Field, Athabasca Oil Sands

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Summary

Low resistivity reservoir (less than 10 Ωm deep resistivity) pay zones are observed in a portion of Devon's Pike lease in northeastern Alberta, Canada. Observations suggest low-resistivity is due in part to high-salinity formation waters, result of mixing with saline Devonian formation fluids. These pay zones occur immediately west of the Prairie Evaporite dissolution edge and are associated with an erosional feature on the pre-Cretaceous unconformity. Additionally, the geometry of the pay also raises questions about migration pathways and highlights the possibility of charging via the underlying Devonian strata.

Introduction

The Devon-BP Pike field is located in the southern part of the Athabasca oil sands deposit in TWP 73-75 and RNG 4-7W4 (Figure 1). Bitumen pay at Pike occurs within the McMurray and Wabiskaw Formations. Locally there is an area of McMurray bitumen saturated sand that appears wet on deep resistivity wireline logs and has resistivities of <10 Ωm (Figure 2). These resistivity values are roughly the same reading as wet zones elsewhere on the Pike lease. Core observations of both the low resistitivy pay interval and laterally adjacent wet zones confirms these trends.

In addition to the low-resistivity pay, the other curious characteristic of this pay is that it occurs where the pre-Cretaceous unconformity is at the structurally lowest part of the lease. Wet sands occurs laterally adjacent and connected to the low-resistivity pay.

This leads us to two questions: 1) what is causing the low resistivity response in the pay zone? and 2) what is causing the geometry of the pay interval where the low resistivity bitumen is mapped?

Theory and/or Method

While the mineralogy of the McMurray Formation sands is consistently quatrzose within Pike, the low resistivity response in the pay zone has to be either a fluid or minerological response. Salt precipitation on mudstone and siltstone intervals in the core suggest that the formation water was highly saline. Petrophysically, deep resistivity logs respond to the high salinity and read low values, whereas the microresistivity log responds to the drilling mud salinity and provides a more consistent reading and better represents the oil saturations in the interval of interest.

The saline formation water is believed to have been sourced from the underlying Devonian rock. Seismic and well-log data indicates no significant dissolution of the Prairie Evaporite Formation within the Pike lease, but the western edge of the partial dissolution front occurs less than 10km to the east (Hauck et al., 2017; Baniak and Kingsmith, 2018). A map of the pre-Cretaceous unconformity shows little evidence for any karsting or faulting in the area. Relief on the pre-Cretaceous unconformity is therefore largely due to erosion caused by channel deposits into the underlying Beaverhill Lake Group. The Firebag Member subcrops below the deepest point on the pre-Cretaceous unconformity locally.

The geometry of the bitumen in this part of the lease is characterized by a highly-variable oil-water contact. For example, between wells 1AA/09-09-074-05W4 and 1AA/01-09-074-05W4, a lateral distance of 600m, the oil-water contact changes by 37m vertically (Figure 3). Along the deep trend on the pre-Cretaceous unconformity, bitumen is charged to the unconformity, which confines it in an east-west orientation and the variable water contact is apparent to the north and south. To the south, the contact is influenced by depositional boundaries, but to the north, there is no identified stratigraphic or structural control on this contact. Cored sandstone in the wet rock shows no residual oil saturation suggesting that bitumen was never present.

Viscosity profiles of the bitumen charged section show highest viscosity at the base of the section, decreasing upwards. Gas Chromatography-Mass Spectrometry (GCMS) analysis of alkylphenanthrene profiles suggest zonation of charged intervals, with the most heavily biodegrated toward the base of the section, suggesting that the biodegradation intensity was greatest at the base of the section in proximity to the oil-water contact (Fustic et al., 2013)

Bitumen charged reservoir to the structurally lowest part of the lease, with a sharply changing bottom water contact laterally, leads to a question about migration pathways. Has bitumen migrated through McMurray strata and locally filled downward or has bitumen migrated into the reservoir from the underlying Devonian carbonates? If the first scenario, what is the mechanism for filling downward and confining to a localized area? If the latter scenario, which carbonate rocks are permeable enough to migrate oil from the source rocks subcropping to the west (Adams et al., 2013)?

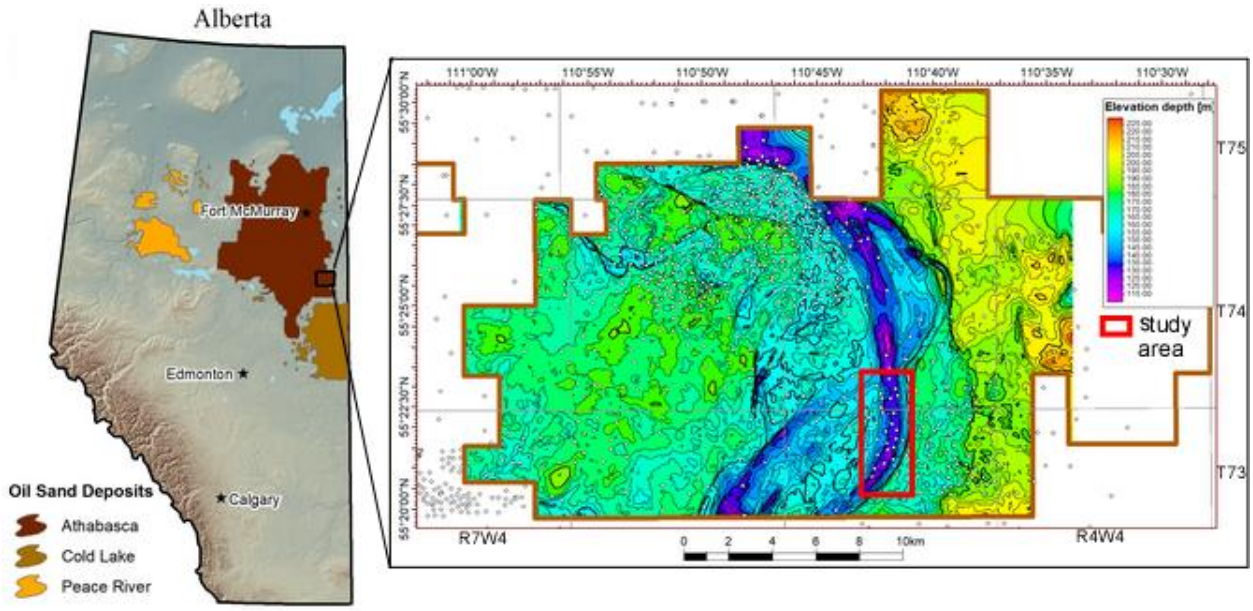

Figure 1 – Location map of Pike Lease (left) and structure map of the pre-Cretaceous unconformity (right). Study area is highlighted in Red.

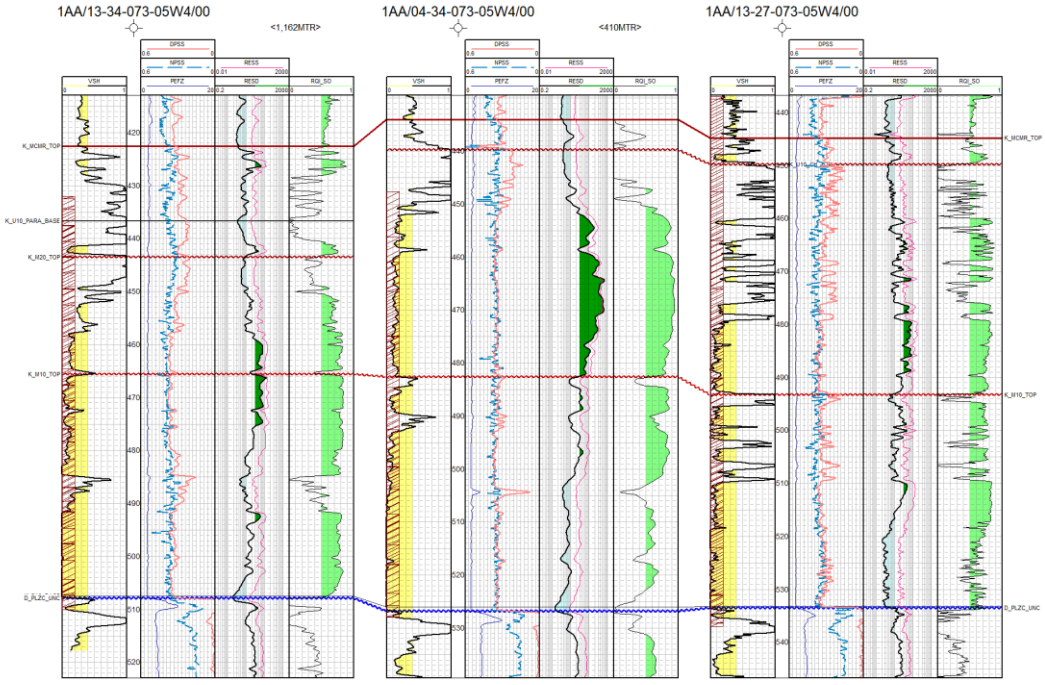

Figure 2 – Cross section through three wells with bitumen-charged sands that read pay at low resistivities. Displayed core from the 1AA/04-34-073-05W4/00 well.

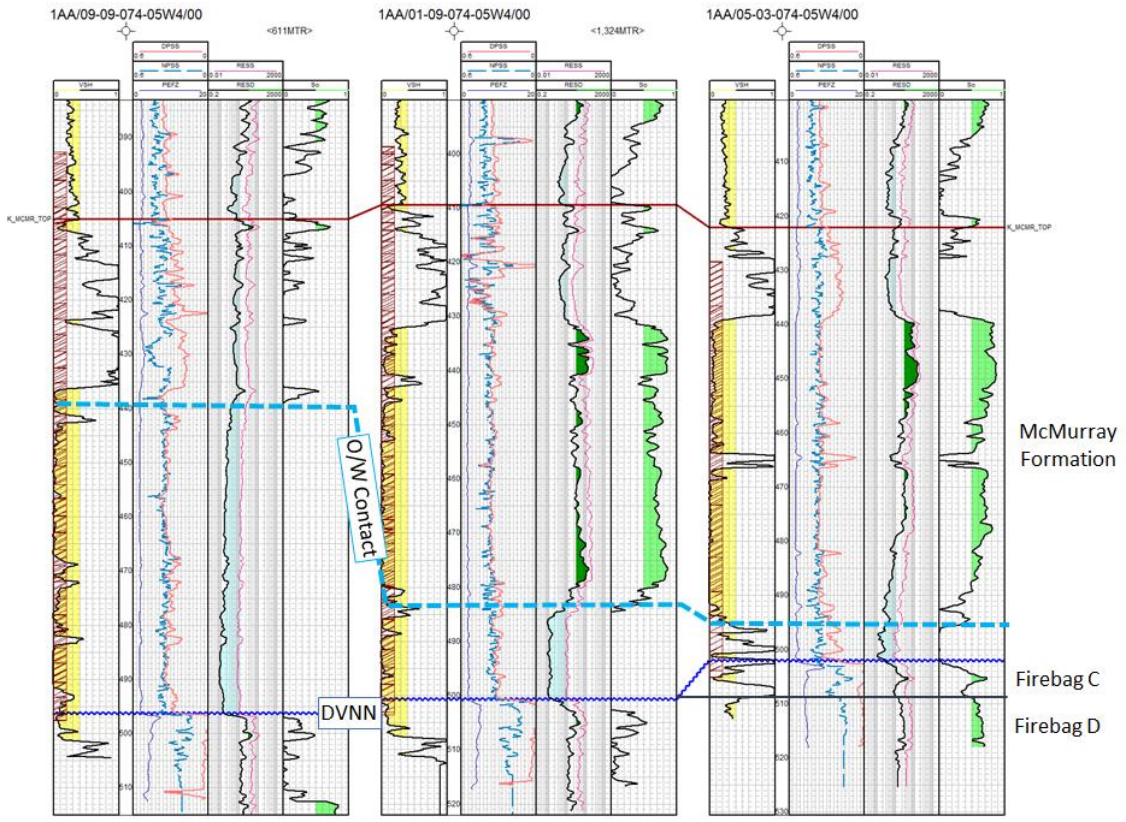

Figure 3– Cross section through three wells demonstrating the sharply changing oil water (OW) contact and Cretaceous incision through the Waterways Fm into the Slave Point Formation.

Conclusions

Observations from core on the Pike lease suggest that in places where the subcrop below the pre-Cretaceous unconformity is within the Firebag Member, there is a mixing of high-salinity formation water into the McMurray. Where bitumen is present, this suppresses the deep resistivity response on logs, making the bitumen charged interval appear wet.

Bitumen charged reservoir rock is observed at Pike occuring locally at the point where the pre-Cretaceous unconformity is near to the lowest structural elevation. This is a charge migration pathway conundrum as the observed geometry is difficult to explain from a fill-and-spill method through the McMurray.

Acknowledgements

Thank you to subsurface staff at Devon and BP. In particular: Adam Leather, Matt Abrams, Duncan Findley, Bryce Jablonski, Gerry Peters, Kelly Kingsmith, Justine Sagan, Scott Barlund, Michelle Parmar, Greg Baniak, Ahmed Iftikhar.

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