Lower Cretaceous Mannville Oil Sands Prospect in the Buffalo Head Hills – Peerless Lake Region, Northern Alberta:

Petroleum Generation, Migration, and Biodegradation

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Summary

A potential oil sands resource that has not been fully realized lies in the Bluesky/Gething Fm. of the Buffalo Head Hills – Peerless Lake (BHH-PL) region of northern Alberta. The average bitumen saturated sand interval spans 10-12 m of localized, discontinuous reservoirs over an area of approximately 18,275 km^2. BHH-PL region oils seem to be genetically related to the rest of Alberta heavy oil and tar sand (HOTS) deposits sourced from the Devonian-Mississippian Exshaw-Bakken Fm. and/or the Jurassic Fernie Gp. (Gordondale and Poker Chip Mbrs.). Through geochemical analysis [gas chromatography-mass spectrometry (GC-MS)] of numerous cored intervals, specifically AA/04-18-088-08W5/0, the level of biodegradation in BHH-PL region was assessed to be greater than the neighbouring Peace River Oil Sands (PROS) to the west and equal to or less than the Athabasca oil sands to the east. Severe levels of biodegradation make the use of common biomarkers (steranes and hopanes) practically unusable to determine the source; however, more resistant compounds track the oil source and maturity, showing it to be similar to the Peace River and Athabasca bitumens. The conventional oils that filled these reservoirs experienced varying degrees of biodegradation related to reservoir geometry and fill history, with better quality oil at the top and poorer quality oil at the base of the reservoirs. Geological heterogeneities in these reservoirs have an impact on the level of biodegradation and the geochemical profiling can identify significant geological barriers to fluid flow. Initial oil quality, charge history, temperature and the thickness of the bitumen saturated intervals were key elements in controlling the level of biodegradation and oil quality.

Introduction

The Buffalo Head Hills – Peerless Lake (BHH-PL) region of northern Alberta is currently a prolific conventional oil and gas producing area and also has an under-explored diamond potential, in an area of roughly 18,275 km^2 (Energy and Utilities Board, 2005; Figure 1). The non-marine to marine bitumen saturated sandstones of the lower Cretaceous Bluesky/Gething formations host highly biodegraded oil and rests unconformably on Devonian and Mississippian carbonates. The ERCB recognizes the Bluesky/Gething interval in the southern BHH-PL (088-08 W5M) as part of the Peace River Bluesky/Gething (PRBG) HOTS deposit. To gain insight into the origin and character of these Mannville

Gp. deposits and their economic feasibility, geochemical analyses were conducted on a number of cored intervals (AA/04-18-088-08W5/0 is highlighted here).

Typically, wide variations in oil chemistry, and fluid properties are observed in all the oil sands deposits (Larter et al., 2006). This study shows that this is certainly the case for the resources in the BHH-PL region, which are highly or severely biodegraded and require in-situ thermal recovery methods. Recent studies have shown that the level of biodegradation is strongly controlled by the genesis of the oil and geological character of the reservoir over its residence time. Here we investigate the geology of some representative sections of the BHH-PL region oil sands and correlate the oil properties to the reservoir character.

Theory

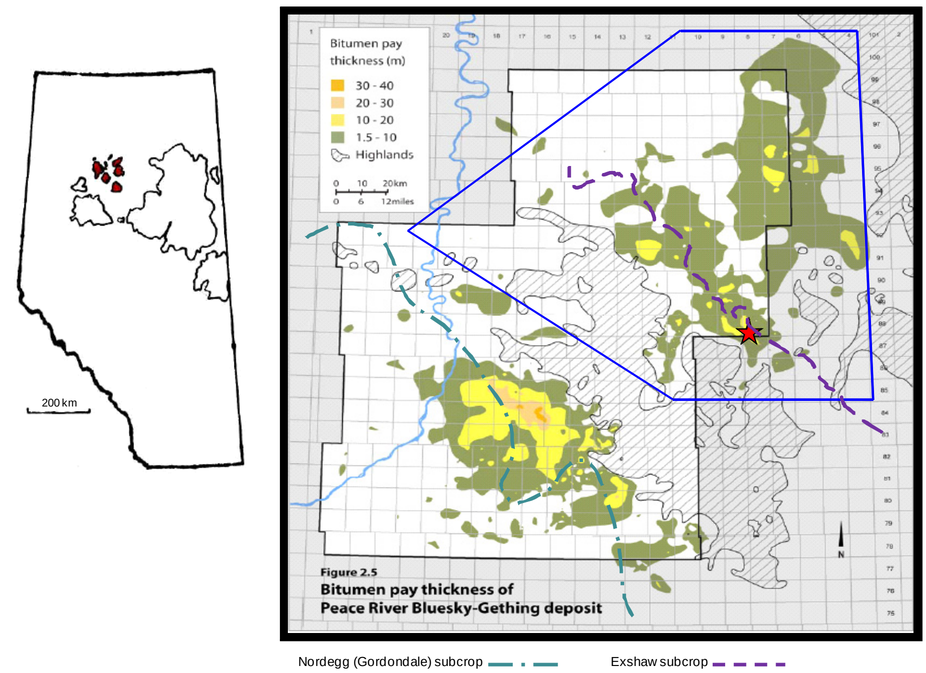
In the study area, the Late Aptian/Early Albian Bluesky/Gething was deposited directly on top of the sub-Cretaceous unconformity and is composed largely of westerly derived marginal marine siliclastics. A chain of Paleozoic highlands (Red Earth Highlands) provided localized sediment sources and strongly affected sedimentation at the time (Hubbard et al., 1999). This has significant implications on the geometry and distribution of the BHH-PL reservoir sands. Ichnological evidence by the authors (unpublished) identified the Bluesky/Gething deposits as two distinct sedimentalogical packages marked by a *Glossifungites* intra-formational unconformity. The deposits below the surface are characterized by mudstones with fluvial-deltaic/estuarine fine grained sandstones proximal to Paleozoic highlands classified by Hubbard et al. (1999) as “quiescent brackish bay” deposits of the Ostracode Zone. Further transgression placed above the surface medium grained, more fully marine fluvial-estuarine and shoreface sandstones (Bluesky Fm.) followed by marine shales (Wilrich shales) that cap the interval.

Conventional oils, largely generated during Laramide tectonics, migrated up-dip through vast carrier systems over hundreds of kilometers northeastward/eastward into Mannville Gp. sands; however the source rocks of the oil sands are controversial. Brooks et al. (1988) used geochemical methods to suggest a major single source contributor for all of the oil sands; the Devonian-Mississippian (Exshaw-Bakken Fm.) or the Jurassic (Fernie Gp.) are considered the two best candidates. Others contest that more then one source contributed to these resources (Allan and Creaney, 1991). Interestingly, Mississippian strata (including the Exshaw Fm.) does subcrop within the BHH-PL area directly beneath the main HOTS deposits (Figure 1), making the BHH-PL area the end of a secondary migration pathway. The Triassic source rocks are not thought to be significant contributors and a more probable source is said to be the Jurassic Gordondale Mbr. that consists of type IIS kerogen with immature source rock parameters of TOC 16 wt.% and HI 759 (Riediger, 1994). Recent 4D modeling suggests that the Jurassic Fernie Gp. (Gordondale and Pokerchip Mbrs.) was a primary contributor, expelling twice as much oil as all other source rocks (2,980 billion barrels) and having a short migration distance enhance by the sub-Cretaceous unconformity (Higley et al., 2009) (~ 100 km to reach the BHH-PL reservoirs). The high sulpher content of the type IIS kerogen, which would have generated oil at very low maturity and very low API gravity, have lead some to speculate that much of the oil was immobile (Riediger, 1994).

Examples

A series of cored sections in the Bluesky/Gething from wells in this area were investigated. Here we discuss AA/04-18-088-08W5/0 as an example. Nine samples were obtained at 1-1.5 m intervals within a 12 m oil saturated zone. Triaromatic steroids are relatively unaffected by biodegradation thus ratio cross-plots

(C27/C28R vs. C26/C28S) suggest a uniform oil maturity of these samples (Mackenzie et al., 1982b). This data also points to a single oil source or good mixing of sources which is consistent with other HOTS deposits of Alberta. The total hydrocarbon concentrations from solvent extracted oil from core analyzed by GC-MS data indicate that all of the samples are severely biodegraded to average levels of 5 to 7 on the Peter and Moldowan (PM) scale. Aromatic compounds (naphthalenes, phenanthrenes, etc.) have been significantly altered (Figure 2) and even the fairly resistant steranes and hopanes show noticeable alteration at the base of the reservoir interval (Figure 3). The oils at the bottom of the oil column are more degraded than those at the top, which is likely where nutrient rich waters would have enhanced microbial activity (Larter et al., 2003; Figure 3). Other samples within the area exhibit similar trends, that is, generally high levels of biodegradation, more degraded than there nearby Peace River counterparts, but there is still significant variability from core to core. In the middle of the reservoir there is a calcite cemented zone, above which the oil is much better quality than the oil at the base of the reservoir near the oil-water contact. This suggests that upper compartment filled quickly down to the cemented zone, thus curtailing nutrient delivery to the biodegradation zone, while the oil in the lower compartment continued to be in contact with sufficient water to stimulate biodegradation.



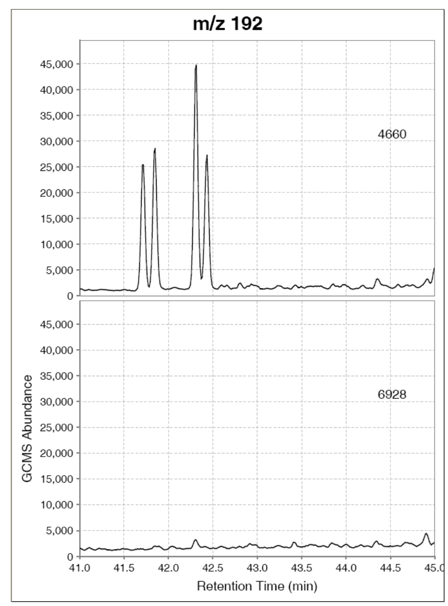


Figure 1: BHH-PL (shaded red) in relation to other major Alberta oil sands (modified from Brooks et al., 1988). Bitumen pay isopach of the Peace River Oil Sands area (black polygon) as outlined by the Alberta Energy and Utilities Board (2007). The BHH-PL study area (blue polygon) is shown, with the red star indicating the cored interval in AA/04-18-088-08W5/0. Nordegg (Gordondale) subcrop in the blue dashed line is taken from Riediger (1994) and the Exshaw subcrop in the purple dashed line from the EUB (2005).

Figure 2: Mass chromatogram (m/z 192) showing severe biodegradation of methylphenanthrenes in sample #6928 (least biodegraded sample from AA/04-18-088-08W5/0) compared to a PROS standard oil.

Conclusions

The under-explored BHH-PL oil sands deposit is a key prospect, despite being more biodegraded than neighboring deposits to the west (PROS). The thin pay reservoirs are still considered economically feasible given that Athabasca deposits are of equal or lesser quality. To enhance recovery in such a deposit the effects of viscosity increase at the base of the reservoir caused by increased biodegradation must be considered. The increase in biodegradation in BHH-PL versus PROS may be related to the longer residence time of these oils which were charged first in these more easterly reservoirs or the potentially low quality, low maturity precursor oil sourced by the subcropping Exshaw into this area. In addition, the relatively thin reservoirs in the area have large oil-water contact surface area to oil volume ratios making them susceptible to enhanced biodegradation (Larter et al., 2006). These highly biodegraded oils show classic compositional gradients and highlight the impact of geological heterogeneity on biodegraded oil quality.

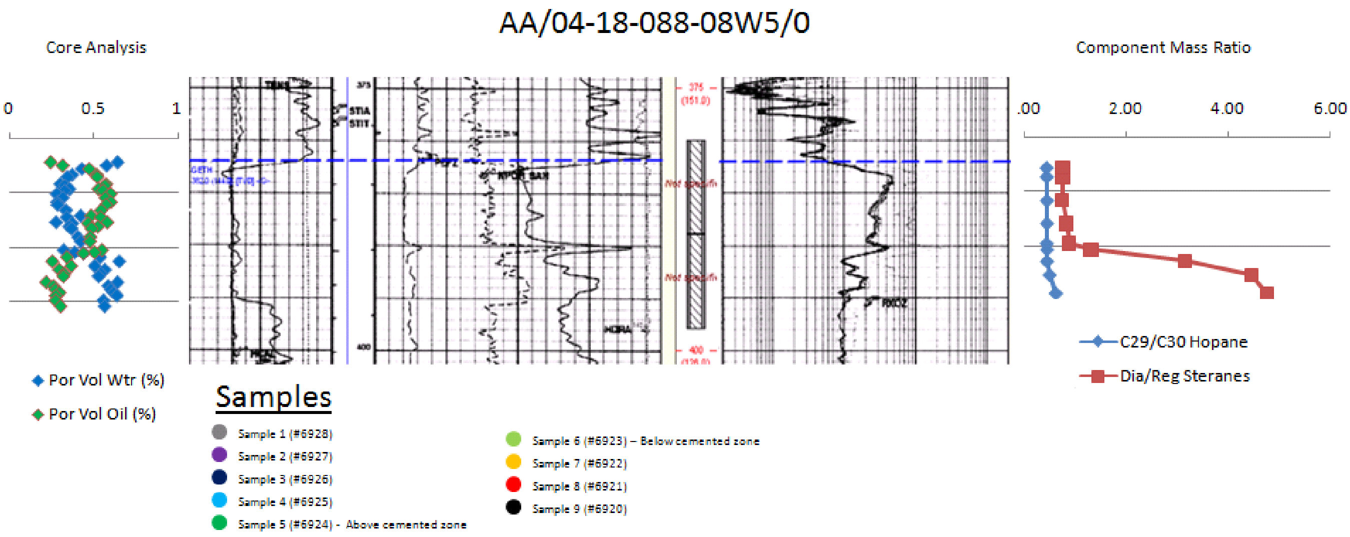


Figure 3: Correlation between core analysis, wireline logs, and geochemistry for the studied core interval of AA/04-18-088-08W5/0. C29 hopane and diasteranes are more resistive compounds and therefore their respective ratios increase due to severe biodegradation. (core analysis obtained from Geoscout, accessed on February 24, 2009).

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