AAPG Datapages/Search and Discovery Article #90174 CSPG©2014 CSPG/CSEG/CWLS GeoConvention 2012, (Vision) May 14-18, 2012, Calgary, AB, Canada

Exploiting the natural variation in fluid properties in heavy oil and oil sands reservoirs:
Geochemical fingerprinting supporting well placement

Barry Bennett, Gushor Inc.,Bay #2 925 – 30th Street NE, Calgary, Alberta, Canada. bennettb@gushor.com
and
Magda Ciulavu, Husky Energy Inc.
707 – 8th Avenue SW, Calgary, Alberta, Canada.

Summary

The stratigraphic well data was used to map the vertical variation in fluid properties (viscosity) and establish correlations with hydrocarbon compositions. This process requires high quality viscosity measurements and accurate hydrocarbon quantification. The baseline data reflects the typical increasing viscosity trend, matched by gradual compositional alteration on progressing down through the oil column. The high resolution maps based on fluid composition and physical properties can be used to determine the vertical aspect of horizontal wells drilled at varying depths in the oil column. In addition, the composition of the first fluids produced during the start-up stage of steam assisted gravity drainage (SAGD) is similar to the compositions characterizing the zone immediately surrounding the horizontal well bore. Furthermore the development and vertical progression of SAGD chamber may be assessed by produced fluid compositions since the vertically advancing steam chamber will access zones corresponding to improving oil compositions.

Introduction

Heavy oils and bitumens are formed by microbial degradation of conventional crude oils over geological timescales introducing lateral and vertical variations in fluid properties (Larter et al., 2008) which can be exploited in a number of applications. However, all the work and results are in vain, if the original studies are performed on samples that have been stored for periods of time, since it has been established that oil properties deteriorate during storage (Adams et al., 2008). Bearing this in mind, it is recommended that measurements of dead oil viscosity are performed as close to the time when the core was recovered from the reservoir. Since revising the protocol for securing samples for dead oil viscosity measurements, we typically find strong correlations between hydrocarbon composition and viscosity i.e. increasing alteration of the oil composition correlates with increasingly viscous oils. We describe the opportunities that exist for gathering useful information from cuttings samples and produced oils from thermal recovery operations, in cases where a baseline study of viscosity and hydrocarbon composition has been conducted on fresh core samples obtained from a vertical cored well.

Methods and approach

A suite of oil sands core samples from a vertical cored well (V1), drilling cuttings from horizontal wells (Hz 1 and Hz 2) and a produced oil (PO) following recovery by SAGD. All of the samples were processed using chromatographic methods that afford the recovery of a total hydrocarbon fraction that is amenable to gas chromatography – mass spectrometric (GCMS) analysis. Since the study involved processing different sample matrices i.e. cores, cuttings and produced oils, the analytical procedure was normalized to single consistent protocol to ensure statistical conformance amongst the sample suite and avoid issues such as batching. The distributions and concentrations of several saturated and aromatic hydrocarbon compounds were monitored, although the procedure herein is demonstrated using the methyldibenzothiophenes (MDBTs). A sub-set of core samples from well V1 were processed using mechanical extraction to recover oil samples for dead oil viscosity measurements.

Results and Discussion

Figure 1 shows the profiles of the dead oil viscosity and chemical composition (MDBTs = Methyldibenzothiophenes) that are generated from the core samples from well V1. It is easy to see that the increasing viscosity down the oil column is matched by a concomitant deterioration (biodegradation) in MDBT concentration data and their distributions (m/z 198). Basically biodegradation of the MDBTs is occurring, while the more biodegradation resistant compounds such as pentamethylnaphthalenes (P) display increasing contributions compared to the MDBTs (Fig. 1). The hydrocarbon composition data and the viscosity from the vertical core well may be processed using chemometric methods (ProxVisc™) which builds correlations between viscosity and the oils hydrocarbon fingerprints or concentration data. The hydrocarbon composition may be obtained from the oils extracted from cuttings samples or produced oils and submitted to the ProxVisc™ in order to generate predicted viscosity data.

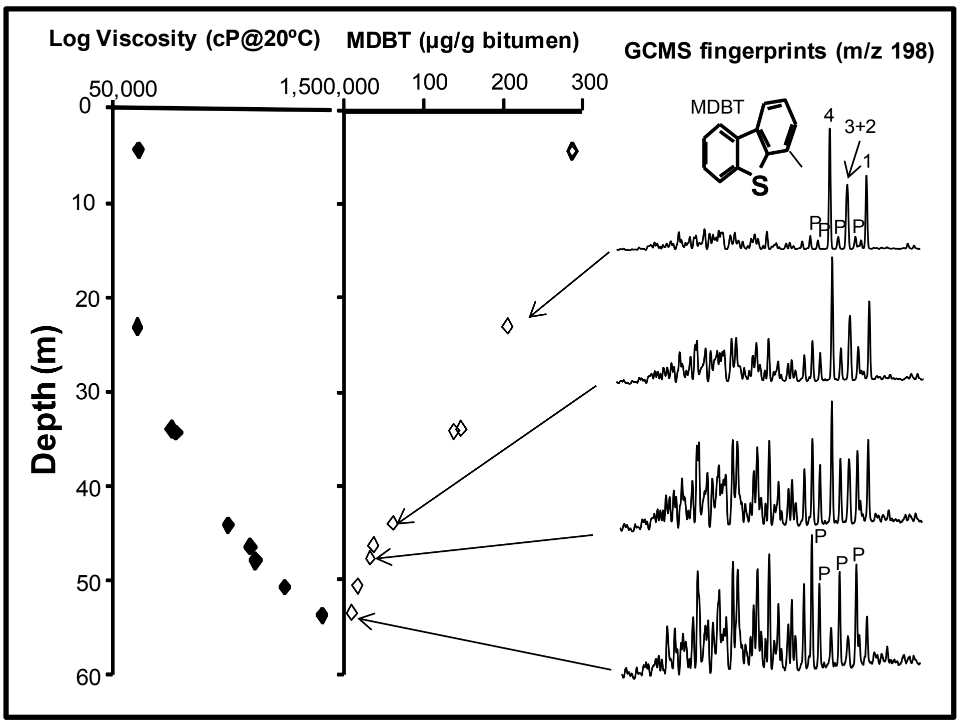

Figure 1. Profiles of viscosity (cP at 20 ºC) and aromatic hydrocarbon compound concentrations and distributions (m/z 198) versus depth (m) for cored well V1. Key: 4 = 4-MDBT, P = pentamethylnaphthalene.

Considering that SAGD wells are typically located at the base of pay to maximise recovery of the resource, based on the predictions from the baseline data set on the profiles of oil viscosity versus hydrocarbon compositions (Fig. 1), it is likely that the cuttings collected and analysed from a horizontal well placed towards the bottom of the oil column is typically expected to show fingerprints characterized by highly altered compositions.

The bitumen was extracted from cuttings from horizontal wells to provide geochemical fingerprints and concentration data. The characteristics of the oil at the depth where the wells are actually placed (such as viscosity) may be predicted employing the data from the baseline study (well V1). A comparison of the predicted viscosity or the hydrocarbon composition data for drilling cuttings against the actual values obtained from the core samples from well V1 may be used to indicate the vertical aspect of the horizontal well placement.

Figure 2 shows the composition of the cuttings from horizontal well Hz 1 which was placed close to the oil-water contact at the lowest point in the reservoir. The fingerprint and concentrations of MDBTs (15 µg/g bitumen) are at an advanced level of biodegradation which correspond to the composition of the core obtained from the bottom of the oil column at 53.5m (Fig. 2). The depth correspondence of the MDBT concentrations (15 µg/g bitumen) from well Hz 1 against the vertical well (V1) falls within the two samples originating from the bottom of the cored well and a viscosity of ca. 1,000,000cP. The horizontal well formed part of a SAGD well pair which subsequently underwent production operation. The produced oils first emanating from the oil zone in contact with the steam also showed highly altered oil composition that actually correspond to the zone where the wells were placed (Sample PO, Fig. 2). Incidentally, the produced oil originating from the reservoir shows a composition of highly altered MDBTs and the concentrations approximated 25 µg/g bitumen. The MDBT concentrations compared to the vertical well V1 lies between the 2^{nd} and 3^{rd} bottom samples which coincidentally give ca. 450,000 – 700,000cP and thus represents an improvement in the oil composition compared to well Hz 1 (producer well) indicating the oil most likely driven from around the injector well that is a few meters higher in the oil column. In summary, the hydrocarbon composition of the produced oil may be used to indicate the likely depth range in the oil column where the oils originated during production.

During SAGD, as the steam chamber grows vertically, it is anticipated that the oil composition mobilized into the production stream should actually display an overall improvement in the oil properties (viscosity and compositions) as the steam chamber accesses the oil higher into the oil column. Incidentally, from the data shown in Figure 1, if the steam chamber mobilizes oil from close to the top of the oil column, then amongst the composition it would be expected that oils would contain intact MDBTs and a higher concentration of such compounds.

A second horizontal well (Hz 2) was drilled at an increased distance (relative to well Hz 1) from the bottom of pay, higher into the oil column shows an overall improvement in oil composition (as well as viscosity). The concentrations of the MDBTs from the second horizontal well were in the range 95 to 54 µg/g bitumen from heel to toe, showing an overall decrease in oil quality and changes in the relative abundance of MDBTs versus pentamethylnapthalenes (Fig. 2) along the horizontal well bore, although the sample obtained from the heel probably contained cuttings from higher in the oil column. The concentrations of MDBTs from the cuttings were assigned to the plot of MDBT concentrations from well V1 correspond to a depth ca. 43-48m from the top of the oil column which correlates with viscosity of ca. 300,000cP.

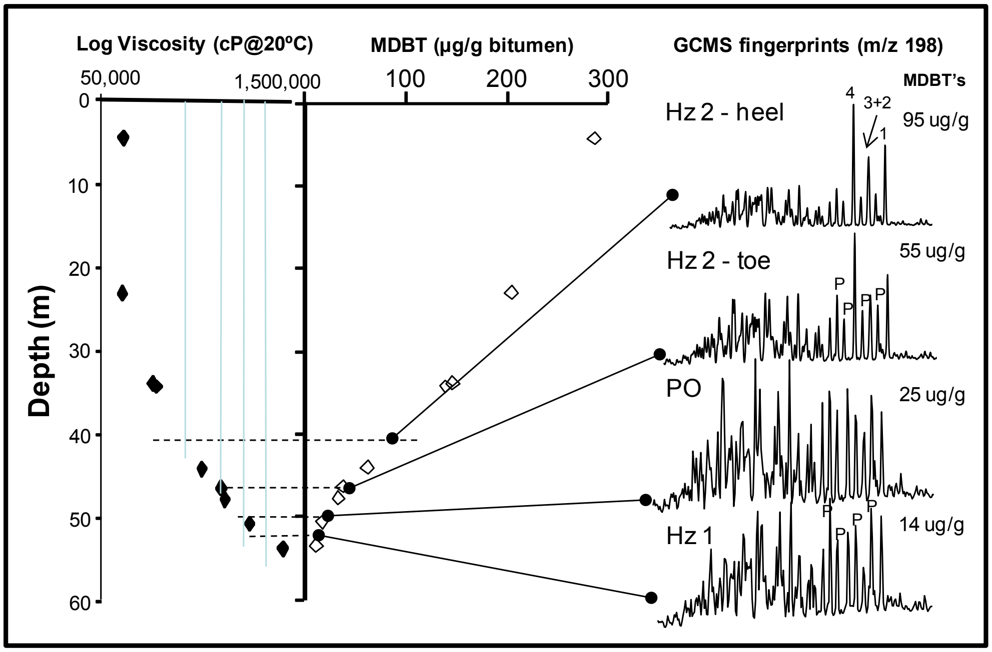

Figure 2. The distributions and summed concentrations of MDBTs in cuttings from 2 horizontal wells (Hz 1 and Hz 2) and a produced oil (PO), and the depth correspondence where the MDBT concentrations are compared to the concentration and viscosity data from the vertical cored well (V1).

Conclusions

The variation in hydrocarbon composition and oil viscosity encountered in heavy oil and oil sands reservoirs provides unique opportunities to map the variation in resource quality both laterally and vertically to better define fluid property distributions. Following the establishment of a baseline data set on a vertical well, the compositions of cuttings from horizontal wells may be used to define the vertical aspect of the horizontal wells, while the analysis of produced oils can provide an indication of vertical progress of the steam chamber advancement during SAGD.

Acknowledgements

The authors wish to thank Husky Energy and Gushor Inc for providing support and permission to publish.

References

Adams, J.J., Jiang, C., Bennett, B., Huang, H.P., Oldenburg, T.B.P., Noke, K., Snowdon, L.R., Gates, I.D., Larter, SR.., 2008. Viscosity determination of heavy oil and bitumen: *Cautions and solutions. Paper 2008-443 World Heavy Oil Conference Edmonton 2008.*

Larter, S., Adams, J., Gates, I.D., Bennett, B. & Huang, H. (2008). The origin, prediction and impact of oil viscosity heterogeneity on the production characteristics of tar sand and heavy oil reservoirs. *Journal of Canadian Petroleum Technology* 47, 52-61.