# A synergy with geoscience discipline for a breakthrough in engineer's issue─Multidisciplinary case study of asphaltene flow assurance

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## Summary

For a robust asphaltene flow assurance engineering, engineers were motivated to evaluate inconsistent asphaltene onset pressure (AOP) measurement results in which AOPs could be detected from some samples while not detected from other ones, even fluid samples were collected from the unique carbonate oilfield. However, the study by a conventional engineering approach could not work. Then, a multidisciplinary approach was performed by a synergy between engineering and geoscience to assess the uneven distribution of asphaltene precipitation risk. The work incorporating geosciences aspect succeeded to well explain the correlation between asphaltene precipitation risk distribution and hydrocarbon migration history. Finally, this work achieved to reduce uncertainty for understanding asphaltene precipitation risk. It also added useful discussions for asphaltene flow assurance engineering from cost saving potential point of views.

## Introduction

Many alerts have been reported that lighter oil precipitates asphaltene more easily compared with heavy oil due to lower solubility, even though heavy oil has much higher asphaltene content. On the basis of recognizing this alerts, our light oil case initiated its risk evaluation since the development phase for a robust asphaltene flow assurance engineering. From seven wells, fluid candidates had been collected to measure AOP values. The assessments were performed as isothermal depressurizing tests at reservoir temperature, followed by expanding the temperature range from reservoir to surface facility's operating conditions to achieve realistic evaluation. However, the results confused engineers because AOP detections apparently varied and depended on fluid samples. Three AOPs were detected at reservoir temperature. On contrary, AOPs were not detected for other three fluid samples at reservoir temperature while detected below. The measurement was cancelled for another fluid sample because of little asphaltene content in the pre-screening. It was a major challenge to seek the cause of contradiction that was disturbance to appropriate asphaltene flow assurance engineering in the field.

## Theory and/or Method

Uncertainty of AOP results, namely conflicts between AOPs detected from some samples while not from others, are not rare cases. Thus, engineers applied the general analytical process to evaluate the variation of AOP detecting results. Engineer's expectation was put on compositional gradients and sampling horizons dependency that could cause these apparent inconsistent results. However, this analytical approach on the basis of engineer's conventional views could not figure out how anomaly of AOP results was caused. Therefore, geoscience discipline was involved into the study team to take more fresh eyes for exploring the truth. Because solid bitumen distribution has been a critical issue to evaluate immovable hydrocarbons in the geoscience discipline, both awareness of the issues; engineer's asphaltene concerns and geoscience's bitumen issue, were efficiently linked to each other. To link idea more clearly, analog field information was reviewed from open source publication. Consequently, an onshore field was found as an analog to our field closely located in the same geological area in the same basin. It consists of Devonian-Carboniferous reservoirs comprising three structures: flat platform interior, a structural higher rims and flank area that includes downslope of the platform. These structures and the sequence stratigraphic framework are quite identical to those of our field. Solid bitumen was reported to exist commonly throughout the analog field, while quite low asphaltene content in the analog field's fluid. Both facts were considered linked to complex history of hydrocarbon migration/entrapment/leakage. The geohistorical modeling studies have proposed multiple stages: at least two stages of hydrocarbon migration for the analog field (Hallager et al. 1997; Schoellkopf and Hallager 1998; Anissimov et al. 2000; Warner et al. 2007). During the multiple migrations, solid bitumen might be formed, based on evidences of geochemistry and petrographics (Warner et al. 2007) with the fluid inclusion study (Tseng and Pottorf 2003). Namely, asphaltene-bearing oil was charged initially, followed by seal failure that resulted pressure decline in the reservoir with brine re-saturating most of the stratigraphic units. Then the seal was re-established to allow a secondary hydrocarbon charge. Solid bitumen was considered to deposit during the pressure decline as a kind of de-asphalting process.

According to bitumen study in the analog field by Walters et al. (2006), solid bitumen distribution depends on stratigraphy and location. The highly fractured rim area contains the most abundant solid bitumen in the shallowest horizon, while less solid bitumen in platform interior. The cause of solid bitumen variability is possibly linked to geological heterogeneity because more rapid pressure reduction might occur in more highly connective fractures, namely rim area, while slower pressure reduction in lower permeable matrix, namely platform interior. Rapid pressure reduction could more severely affect on bitumen stabilization in liquid phase. Besides pressure reduction, oil compositional change was alternative possible event during hydrocarbon migration. In the charge modeling study (Stainforth, 2004), the geological feature determines hydrocarbon distribution. Sequential hydrocarbon migration: initially low maturity and subsequently high maturity hydrocarbon migration, causes fluid mixing in geologic time and might destabilize asphaltene to result solid bitumen (Dumont et al. 2012; Mullins et al. 2012a, 2013b). In fact, Walters et al. (2006) pointed out that the same variation of solid bitumen could be reproduced through the fluids mixing process in the analog field. Because hydrocarbon could migrate through the high permeable fluid flow pathway predominantly, more asphaltene might precipitate than low permeable matrix section in platform interior. This biased flow in high permeable section is considered to distribute more solid bitumen in rim area.

## Examples

Both oil charging scenarios are possible in our field case, too. The total-organic-carbon (TOC) data reveals absolute trends of spatial bitumen distribution. Three main trends are observed by viewpoints. To focus on field-wide large scale trend in horizontally, more solid bitumen can be seen as moving from the west to the east. To focus on locally observing the horizontal variation as a medium scale trend, higher solid bitumen can be placed in rim area compared with the platform interior. To focus on closer observation viewpoints: well location level as a small scale trend in vertically, more bitumen can be observed in the lower compared to the upper horizons. Because higher bitumen deposition is associated with lower asphaltene concentration in liquid oil, the in-situ solid bitumen trends could be interpreted to the asphaltene trends remaining in the liquid phase: higher asphaltene content 1) in the east area compared to the west area, 2) in the upper horizon compared to the lower horizon, and 3) in the platform interior compared to the rim.

Consequently, according to the above interpreted asphaltene trends, AOPs anomaly could be well explained by their sampling locations. Namely, this study could demonstrate a potential to correctly predict asphaltene risk distribution by location. Here, subsequent two potentials are discussed to minimize cost by enlarging application area: surveillance and facility planning. The data surveillance is important to proper reservoir management involving robust asphaltene flow assurance evaluation. Currently, single-phase reservoir fluid sampling has been incorporated into a comprehensive surveillance plan because experimental AOP is the most direct data to represent live asphaltene behavior. However, live oil sample is costly collected. It is tradeoff relationship between evaluation accuracy and its cost. Before this study, there were no clues to select fluid sampling wells. If asphaltene precipitation risk is predictable prior to a new drilling, sampling wells can be selected effectively based on such pre-information. This can minimize the surveillance cost.

In offshore development, inhibitor-dosing plan is considered for each satellite platforms where a number of wells tied-in. For the asphaltene flow assurance in the midstream, the chemical injection is assumed from production manifold or oil header line on satellite platforms. Suppose a satellite platform consists of combination of high/low-asphaltene-precipitation potential wells, it requires treatment even just one well is located in high risk area. On contrary, suppose a platform consists of low-asphaltene-precipitation potential wells only, there might be a potential to save such treatment by various optimization: reducing chemical injection frequency, downsizing or removing pump unit. This can minimize CAPEX and OPEX.

## Conclusions

- The multidisciplinary synergy was well performed with geoscience and engineer disciplines. The apparent heterogeneous asphaltene precipitation risk distribution could be explained to cause due to heterogeneous solid bitumen occurrence that happened during the hydrocarbon migrating time.
- The findings revealed a potential to make asphaltene precipitation risks predictive prior to new drilling. It was considered to be worthy for optimizing future cost-saved surveillance plan or anti-asphaltene operation design.


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