Field Case: the Origin of the Fluid Properties Variation and the Tar Mat

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Abstract

In this work, a field case will be presented to induce discussion on the relevance of the data to be acquired and to be analyzed according to the objectives of the investigation.

In the field case presented, a strong segregation was observed in a connected reservoir. The in situ viscosity of the oil varies from less than 1 cPo for samples taken close to the gas cap, to more than 100 cPo for oil sampled 400 meters deeper. “Tar mat deposits” were also observed in the bottom part, but also in some specific area of the reservoir.

This strong variation of the oil properties in the fluid was so far approximately described by considering a liquid-liquid transition at a specific depth. However, the authenticity of this liquid - liquid transition and the “tar mat deposition” was until then neither proved, nor refuted and the compositional analyses shown no clear fluid organization across the field.

By investigating the characteristics of the asphaltene fractions of the oil and of the core extracts resulting from various places in the reservoir, we were able to demonstrate that the existence of a liquid - liquid transition is very unlikely. Also, we show that the strong variation of the properties of the fluid column is more linked to the filling history of the fluids rather than gravity segregation. Besides, we were capable of differentiating two types of tar mat, one linked to the precipitation and the other one linked to the segregation.

Through this field case, we show that the information such as asphaltene content or SARA composition is poorly helpful for the understanding of the origin of the tar mat and its phase behavior, Investigation of the asphaltene characteristics rather than its concentration in both oil and core extract samples is the key.

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A strong segregation was observed in this field case. The in situ viscosity of the oil varies from less than 1 cPo for samples taken close to the gas cap, to more than 100 cPo for oil sampled 400 meters deeper while the in situ density of the oil varies from 760 kg/m³ to 950 kg/m³. This variation in a connected reservoir was so far approximately described by considering a liquid-liquid transition at a 2285m. However, uncertainty is huge and many other explanations are possible.

In addition, “tar mat deposits” were visually observed in some area of the reservoir.

In order to understand the origin and the nature of such a strong segregation and of the tar mat, 9 oil samples, 13 core samples containing oil and 4 core samples containing “tar mat” from different depth were investigated. We must find the answers to three questions:

- Is there really a liquid-liquid separation at 2285m?
- Is the occurrence of the “tar mat” is due to asphaltene precipitation or is it due to local asphaltene enrichment?
- Is there any logic in the repartition of the tar mat?

To understand the fluid organization, we need to analyze the driving force leading fluid composition variation. As we know, a moderate variation of the fluid composition or properties may induce a strong variation of the asphaltene stability. This means the main driving force is not the concentration of the asphaltene, but the solubilization power of the oil or the solubility class of the asphaltene. Thus,

in addition of the SARA analyses, the Asphaltene Solubility Class Index (ASCI) determinations were also performed.

The oil samples were evaporated at 50°C and 20 mbar prior to investigations in order to eliminate the volatile fractions. The residual oil and the possibly organic deposits in the core samples were extracted at 100°C and 100 bar using dichloromethane. The solvent and the volatile fractions are then evaporated at 50°C and 20 mbar in order to make them comparable to the oil samples.

In spite of the caution concerning the sample pre-treatment, SARA analyses show scattered data with poor organization versus depth..

Inversely, the ASCI measurements show a clear organization of the asphaltene solubility class versus depth for both oil samples and core extracts including two of the four samples visually identified as “tar mat” or “bitumen” (figure below). Two other “bitumen” samples are out of the trend with a much lower ASCI. These samples contain for sure precipitated asphaltenes.

The ASCI mapping on both oil and core extract samples allows us to conclude that:

- Excluding the two samples out of the trend, the ASCI of all samples vary consistently and continuously versus depth which indicates that the occurrence of a liquid-liquid transition around 2850 m is very unlikely.
- The tar mat samples visually observed around 2300 m correspond clearly to precipitated asphaltenes.
- The “tar mat” samples visually observed below 2500 m contain the same asphaltenes than the oil samples from the same depth. It means that they are not “true tar mat” due to precipitation, but correspond to oil enriched in asphaltenes.

- The ASCI and the oil density variation indicate that the asphaltene fraction should be stable, except for the two “true tar mat” samples found in the middle of the reservoir. The most probable explanation on this observation is that the precipitation is induced by the loading of an incompatible fluid over another fluid already in the reservoir. It means that the “true tar mat” is located around the paleo-contact of the two fluids.
- The trend of the ASCI versus depth indicates that the borderline between the two fluids was erased by conversion and diffusion. However, the equilibrium seems to be not archived and the fluid column cannot be correctly represented by a segregation model.