[PS]Optimization of Formation Evaluation by Integration of Advanced Surface Fluid Logging and Downhole Tools in Difficult Geological Settings*

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Abstract

The scope of this paper is to illustrate the successful application of the Advanced Surface Fluid Logging (ASFL) analysis in the X-1 well drilled in shallow waters, offshore Malaysia. The unexplored Block X, located next to the producing fault block on the East flank of the M structure, was proposed for appraisal based on the seismic data interpretation, strongly suggesting continuation of good reservoir quality from the adjacent block. However, uncertainty with regard to the fluid distribution, contacts and connectivity in the targeted stacked reservoirs was still a serious concern. The formation evaluation program for downhole logging was severely impacted by the limited available budget. Pressure tests program was based on logging while drilling evaluation and run in wash out mode. A limited number of downhole samples were planned, which, considering the multilayered nature of the reservoir, were considered insufficient to achieve a full understanding of the targeted reservoirs. Further challenge was the expected borehole instability and the need to reduce the residence time of the downhole tools in the hole. During the wireline operations, serious borehole instability problems were encountered and, prevented the collection of the planned downhole samples, thus drastically reducing the amount of crucial formation evaluation data. The ASFL dataset remained therefore the only information available about the fluid nature and composition and secured vital reservoir data for the initial formation evaluation study of the appraised block.

Optimization of Formation Evaluation by Integration of Advanced Surface Fluid Logging and Downhole Tools in Difficult Geological Settings

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Introduction and Challenges

The unexplored Block X was proposed for appraisal based on the seismic data interpretation, strongly suggesting continuation of good reservoir quality from the adjacent producing block. However, the drilling of the Well 1 posed a certain number of challenges which required the delineation of a thorough formation evaluation plan:

1. Fluid distribution, contacts and connectivity in the targeted stacked reservoirs.
2. Limited formation evaluation program for downhole logging due to budget constraints.
3. Pressure tests program was based on logging while drilling evaluation and run in wash out mode.
4. Limited number of downhole samples was allotted, which, considering the multilayered nature of the reservoir, were considered insufficient to achieve an overall picture of the fluid distribution in the reservoirs.
5. Borehole instability was expected to be a real concern, based on the offset wells study, and consequently it was planned to minimize the residence time of the downhole tools in the hole.

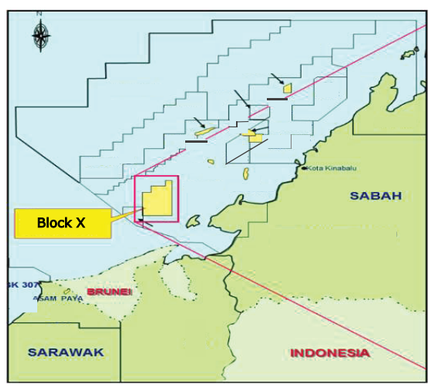

Fig 1 – Field location

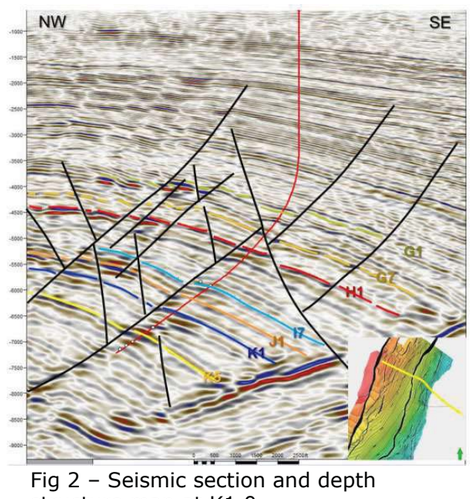

Fig 2 – Seismic section and depth structure map at K1.0

Methodology

ASFL (Advanced Surface Fluid Logging) service was run in combination with the traditional logging while drilling tools to tackle all the expected challenges.

The ASFL technology provides reservoir fluid composition in the C1-C8 range (C1-C5 analogous to the PVT monophasic fluid) by extracting and quantifying the hydrocarbon concentration entrained in the mud column while drilling.

The gas chain is composed of two mud-heating extractors placed respectively at the flow line (extractor OUT) and in the active pit (extractor IN), a non-condensing transportation gas line and a high resolution Gas Chromatograph-Mass Spectrometer (GCMS) analyzer.

A thorough automatic procedure is run to process the data and to achieve the final reservoir fluid composition. Once the recycled hydrocarbon is removed, the final and most critical step is to evaluate the extractor efficiency for each of the extracted hydrocarbon. This is achieved thanks to a dedicated process performed at the rig site, any time a significant change in mud properties occurs.

Some of the great advantages of such technology are to be independent of drilling fluid, borehole geometry, temperature, pressure and provides zero-operational-risks formation evaluation.

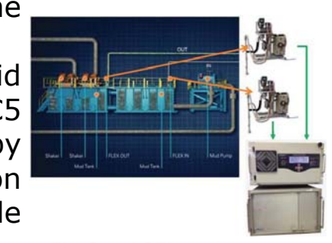

Fig 3 – ASFL technology

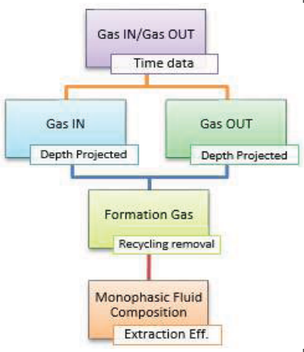

Fig 4 – ASFL data processing workflow

Results

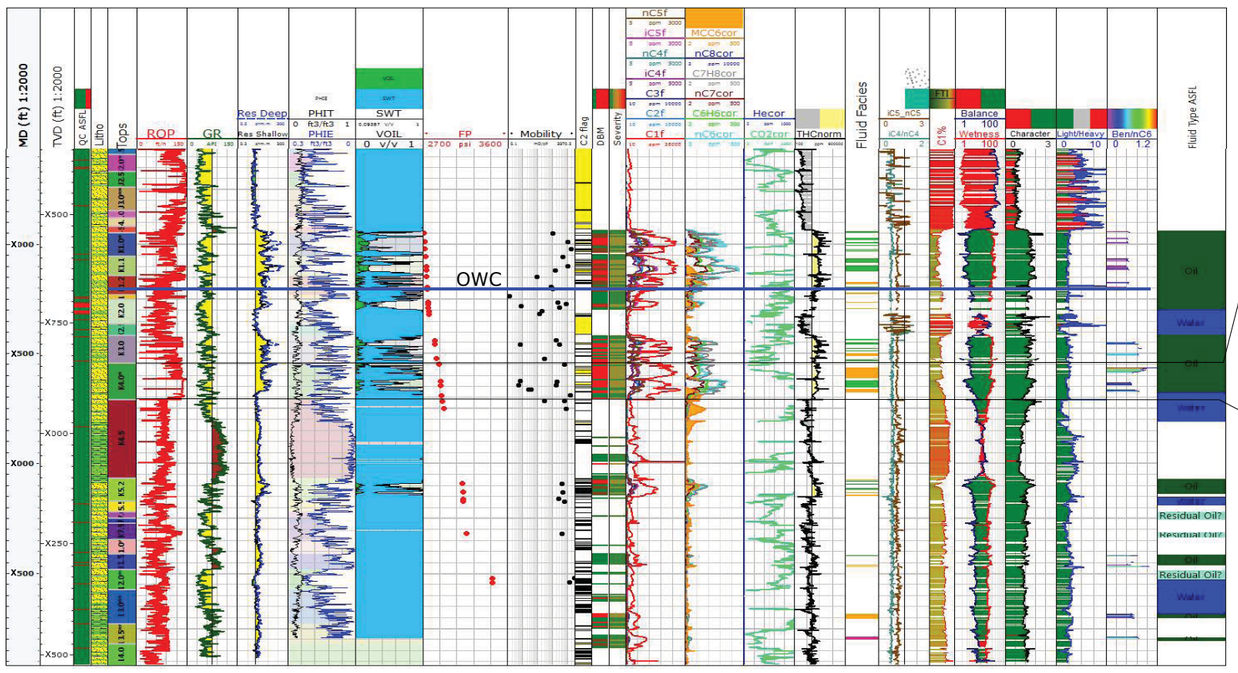

Fig 5 – Integrated Formation Evaluation log

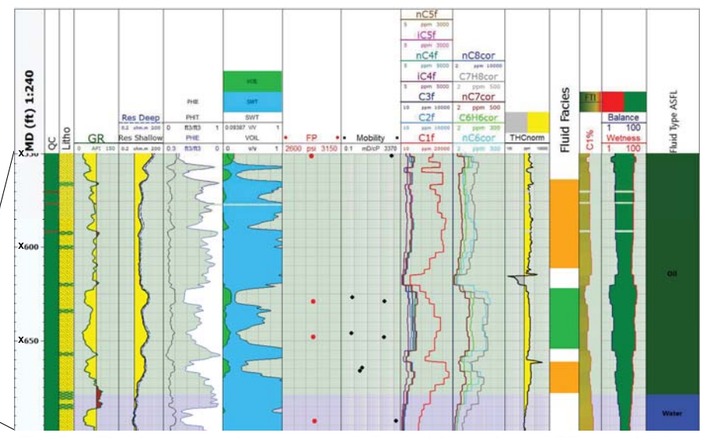

Fig 6 – Fluid type and extra pay inferred based on ASFL analysis

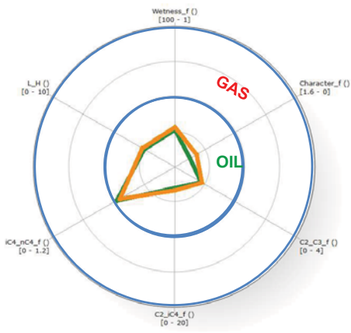

Fig 7 – Fluid Type star plot

Potential hydrocarbon zones are identified while drilling by integrating the conventional LWD tools with the Total Hydrocarbon Content from ASFL technology. By normalizing the THC for the drilling parameters and once all artifacts possibly generated by hydrocarbon recycling, mud contamination and drilling artifacts (i.e. Drill Bit Metamorphism) are removed, the characterization of such zones becomes very trustworthy.

Water zones are then recognized by crosschecking the normalized THC with reservoir zones from LWD.

Fluid fingerprint analysis allowed identifying oil with minor compositional variations in the selected saturated intervals. Table 1 illustrates the **ASFL Fluid Type** calls from ASFL versus the prognosis. **Residual Oil** zones were characterized based on ASFL evidence where LWD and subsequent Wireline data were uncertain.

Pressure tests and PVT sampling depths were selected based on findings from ASFL. Pressure gradients, wherever possible, confirmed the ASFL fluid type.

However, ASFL analysis was decisive to resolve fluid type uncertainty in **thin beds** and where pressure tests were insufficient. **Extra pay** zones were eventually added over the subsequent wire-line logs hydrocarbon zone evaluation.

Due to serious borehole instability problems while logging with wireline, no downhole sample was collected. The ASFL dataset, therefore, remained the only information available about the fluid nature and composition and secured vital reservoir data for the initial formation evaluation study of the appraised block.

Formation	Fluid Type Expected	Fluid Type ASFL	OWC	Sampling Plan
J4.5 Shale	WATER	WATER		
K1.0	OIL	OIL		PVT (SPMC)
K2.0	WATER	OIL/WATER	XX97'MD	PVT (SPMC)
K3.0	WATER	OIL		PVT (SPMC)
K4.0 (Upper Sands)	OIL	OIL		PVT (SPMC)
K4.0 (Lower Sands)	OIL	WATER (f/ XX86'MD)		
K5.2	OIL	OIL		PVT (SPMC)
K5.5	OIL	RESIDUAL OIL?		
K7.0	OIL	RESIDUAL OIL?		
L1.0	WATER	RESIDUAL OIL?		
L2.0	WATER	RESIDUAL OIL?		(MPSR)
L3.0	OIL	RESIDUAL OIL?		(MPSR)
L3.5 (Upper Sands)	POSSIBLE OIL	RESIDUAL OIL?		(MPSR)
L3.5 (Lower Sands)	POSSIBLE OIL	WATER		

Table 1 – Fluid type call from ASFL versus expected and sampling program

Benefits

ASFL technology was successfully applied during the drilling of the well 1 in the Block X to:

- Provide real time continuous fluid composition equivalent to PVT in the C1-C5 range.
- Characterize fluid types (oil, water and residual oil).
- Locate OWC confirmed by the LWD and the subsequent wireline results.
- Provide while drilling insights to select pressure tests and sampling depths.
- Add extra pay over the wireline logs hydrocarbon zones evaluation.
- Reduce uncertainty in fluid typing where formation pressure data is insufficient
- Secure vital reservoir fluid information where borehole instability prevented to collect any downhole sample.

Presented by: Andrea Di Daniel