Revisiting Brown Fields: A lookback on Unforeseen Opportunities in a Late Life Field

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Summary

Late life fields in terms of its subsurface data maturity are often considered to be adequate to fully grasp the subsurface uncertainty associated with the remaining potentials left. Thus, not much investment is put into acquiring new data and often the appetite to revisit the subsurface studies with the latest technologies is less as more consideration is put towards getting access to hard data which could only explain the reservoir uncertainty only within the well radius. However, we have found that by conducting an integrated approach and analysis using all available datasets from multiple disciplines, we are able to enrich our knowledge of the subsurface and to optimize some of the previous workflows applied to drill new infill wells. Application of the latest Machine Learning solutions post drilling; we discovered a new compartment in a brown field which has been producing for more than 50 years. By integrating new geophysical and geological understanding in a late life field within a Malaysia basin, we could hopefully discover new opportunities for future field development plan as well as to gauge on the lessons learned from previous campaigns with regards to the latest data available.

Introduction

Brown fields in Malaysia Basins are known for its diverse environment of deposition (EOD) and for its persistence in continuous production rates which has spanned as long as or even before the formation of the Federation of Malaysia itself. These brown fields are equally distributed between the West Malaysia Peninsula and the East Malaysia regions located within the Borneo Island. During the initial stages of the Field Development Plan (FDP) most of the seismic data was mainly consisting of 2D close spaced Seismic data and limited 3D data was available. Only some of the fields had the opportunity to re-acquire new streamer data once the production has been sanctioned or ongoing. However, given the challenges faced by each field such as Shallow Gas masking as highlighted in Kumar et al (2017) certain fields had to utilize new seismic acquisition technologies in the form of Ocean Bottom Survey (OBS) to fulfill the objective to provide the best seismic imaging for the field.

Our field of study not only face the same challenges as shown in Kumar et al (2017) but also has a large growth fault with multiple antithetic faults spanning Southwest and Northeast direction with a large field size. Getting the best seismic acquisition set-up was paramount to properly illuminate not only the masked zones but also all the fault blocks within the field area. Historically, the field produced its first oil back in 1968 with several redevelopment campaigns being carried out from then up till the most recent major campaign in 2015 which was partially successful. This last campaign faced a major challenge back then due to the mismatch between the results from the Dynamic Model versus the actual well result, leading to 2 wells being dropped from the campaign. Moreover, the discovery of a much larger gas cap prompted the campaign to be halted early due to the high subsurface uncertainty. Given the tectonic history of this field which had multiple history of fault reactivation, the fault throw is quite inconsistent with the well correlation established regionally and within the reservoir units as well.

Thus, a major data acquisition campaign for a new seismic dataset was executed in the same year to provide a new seismic data benchmark replacing the previous streamer seismic data acquired back in 1988 with the goal of resolving the shallow gas masking via OBS survey and utilizing full fledge seismic reservoir characterization study in the form of Seismic Inversion and Facies Inversion. Furthermore, additional support from the latest solutions by the Petrophysics Department was also included as well as new data from Reservoir Engineering were utilized to fully understand the reservoir and subsurface setting.

Methodology

Focus was put into acquiring the best seismic data for the field. Given that the field had complex faulting with shallow gas, OBS survey was chosen to resolve the shallow gas masking issue as much as possible. Ideally, both the PP and PS data would be processed to achieve the said goal. Not only that, consideration in terms of its nominal fold as well as its Trace Density would be imperative as to ensure the seismic product could be used for further seismic reservoir characterization study. Being that this is an actively producing field with active production at 108 strings, the field proximity to the coastline, and a pathway for vessels to dock at the nearby port provides a challenge in terms of managing the noise generated from these activities. Careful planning in terms of data acquisition had to be put in place to ensure not only does the data acquired is of the best quality but also to minimize disruptions towards the production operations and commercial activities nearby.

Once the data was acquired, ensuring the seismic data was processed with consideration that the final seismic data would be used for Quantitative Interpretation (QI). Given that the need for a dense Trace Density was in place as well as consideration for processing the PP and PS dataset, Joint PP-PS Seismic Inversion workflow was implemented for the goal of extracting as much information on reservoirs in this field. Some of the early limitations identified was the lack of Shear Sonic (DTS) logs acquired along the well bore in this field, which may impact the quality and calibration of the seismic inversion product at the end of the processing stage. New drilling campaigns around the time of acquisition had extensive well data acquisition and included the shear sonic logs into its campaign to address the lack of shear sonic data. Moreover, detailed Rock Physics Modelling (RPM) was done for a field specific model to generate the Elastic Properties (Vp, Vs, Density) for the rest of the wells which do not have complete sets of Elastic Properties in their database, as outlined by Yusoff et al (2014). Additionally, other seismic attributes were also applied such as Spectral Decomposition to provide any outline in terms of the geomorphology of the sand bodies in the zone of interest as showcased by Ishak et al (2021).

Complexity in terms of the fault remained one of the biggest challenges for seismic interpretation for this brown field. Hence, by utilizing the latest seismic interpretation workflow assisted with Machine Learning introduced by the in-house research team was applied to ascertain the growth fault extension and to provide indication of the fault throw on the downthrown block. The workflow integrates the usage of Convolutional Neural Network (CNN) focusing on the interpreted surfaces in the seismic with the Relative Geologic Time (RGT) calculated from the seismic itself, which is an independent step from the manual horizon interpretation.

It also considers the discontinuity properties from the seismic to provide additional input for the attention mechanism to optimize the final interpreted surfaces. Moreover, the result could be used to provide an additional indicator for the fault throw based on the input data as the predictive network highlights similar trends or features in the datasets to determine another similar feature on the other fault blocks.

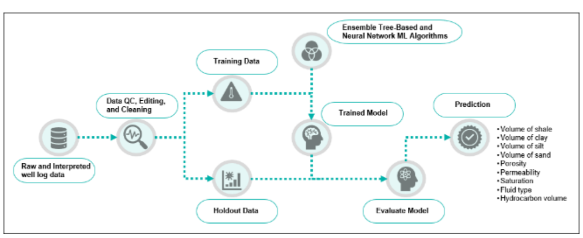

Figure 1: Well Log Data Artificial Intelligence Workflow applied in this field.

Another novel workflow introduced for the field was the application of Machine Leaning based Petrophysical interpretation to guide in terms of identifying new sand intervals with good potentials and to pinpoint any underestimated reservoirs. This is done using the Well Log Data Artificial Intelligence Workflow based on the workflow by Shah et al (2024). By applying this workflow, a field-wide machine learning prediction model was developed using raw well log data as inputs and feature engineering of selected variables including volume of shale, neutron density index and scaled detrended gamma ray. Figure 1 shows the flow chart of the Well Log Data Artificial Intelligence Workflow.

The Well Log Data Artificial Intelligence Workflow had also been integrated with the drilling rig real time data transmission which allowed for real time petrophysical properties prediction based on the Logging While Drilling (LWD) logs.

Results

With the incorporation of the seismic interpretation and seismic workflows based on the OBS survey, a new Oil Redevelopment campaign was approved in 2018 and subsequently a drilling campaign was conducted in 2019 and 2023 respectively. One of the main sands being targeted was determined to be tidal influenced with some distributary channels.

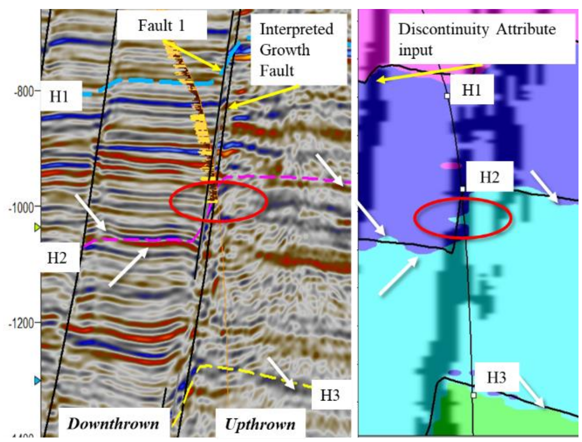

Figure 2: Result from Optimized CNN indicates the fault throw is shallower and located at the downthrown block, which tallies with the result from LWD.

These sands were heavily exploited in a separate fault block within the same field and was found to have strong water drive in the reservoirs. Hence the decision to place new infills in the same sands at the upthrown block southwest of the field was aided with the results coming from both the Seismic Inversion and RGB Blending from the Spectral Decomposition. Figure 3 showcases the comparison between the Seismic Acoustic Impedance Inversion result versus the RGB result at the H2 horizon from initial interpretation.

Upon drilling the first infill well in the field in 2023, some structural uncertainty was discovered in which the base interpretation for the target sand was found to be much shallower than expected and located at one of the downthrown fault blocks. Initial seismic interpretation only took into consideration of a single growth fault which did not undergo reactivation. However, when the well was drilled, it was found to have differing displacements along the fault. Verification tests based on the Optimized CNN workflow post drilling indicated that the initial growth fault interpreted was reactivated at this portion of the field thus making the throw minimal in comparison with the rest of the area. Figure 2 showcases the training dataset versus the test line which indicates the throw being minimal while Figure 4 the subsequent reinterpretation of the fault based on the Optimized CNN Workflow.

Subsequently, during this drilling campaign, LWD was made available and thus the Petrophysical Machine Learning workflow could be applied to these wells prior to the discussion of the completion strategy. Based on the real time application of the Well Log Data Artificial Intelligence Workflow, several reservoirs that were previously not part of the original targets were quickly identified. The predicted reservoirs from Machine Learning were later verified with conventional petrophysical evaluation with satisfactory result. Figure 5 demonstrates the comparison between machine learning prediction and conventional petrophysical evaluation.

The predicted petrophysical evaluation from Machine Learning successfully delineated reservoir quality from clean sands to poor thin beds and correctly identified gas and oil-bearing sands encountered. It also accurately predicted several low resistivity sands with perceived low quality that was not focused on previously. All of this was done near simultaneous with real time LWD data transmission. Having this information quickly allowed the team to modify the completion program to cater for these additional sands, resulting in higher oil production.

Conclusion

New data acquisition from the Ocean Bottom Survey has tremendously improved the understanding of the tectonic setting as well as the fault history of this field, which enabled us to locate remaining oil in untapped fault blocks as well as providing vital insights into reservoir characterization via seismic inversion, seismic attributes, and application of Machine Learning methods to aid in improving the previous seismic interpretation established.

Key findings from Petrophysical interpretations had also been fundamental in terms of highlighting new potential sands which was previously not considered due to its perceived low sand quality as well as its low resistivity response. Introduction of Supervised Petrophysical Machine Learning solutions developed in-house has warranted a serious lookback on this reservoir which could translate to future works in terms of behind casing opportunities as well as new focused infills at other fault blocks. Application of Optimized CNN workflow on this OBS survey also highlighted the structural style to be much different than initially interpreted. Moving forward, lessons learned from the latest dataset has given the field a new lease of life, proving that unforeseen opportunities still exist in a brown field.

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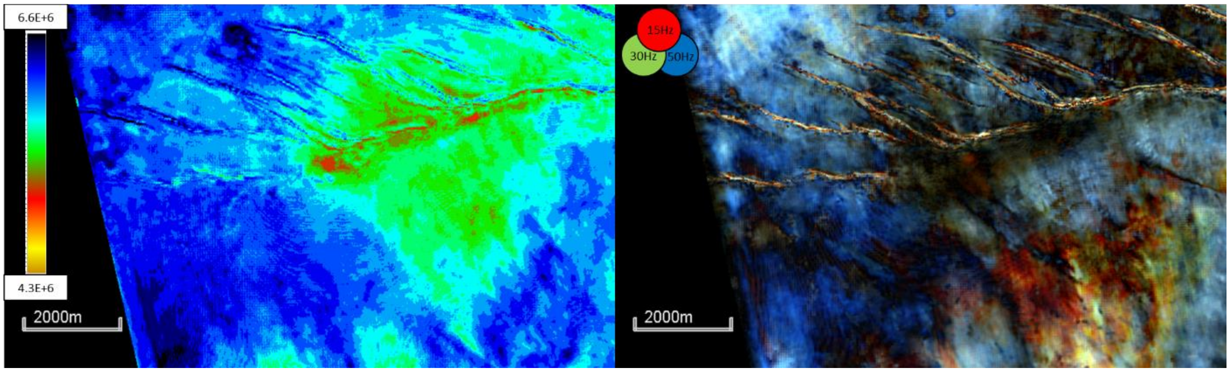

Figure 3: Seismic Acoustic Impedance Inversion result versus the RGB Blending for the field extracted along the H2 horizon.

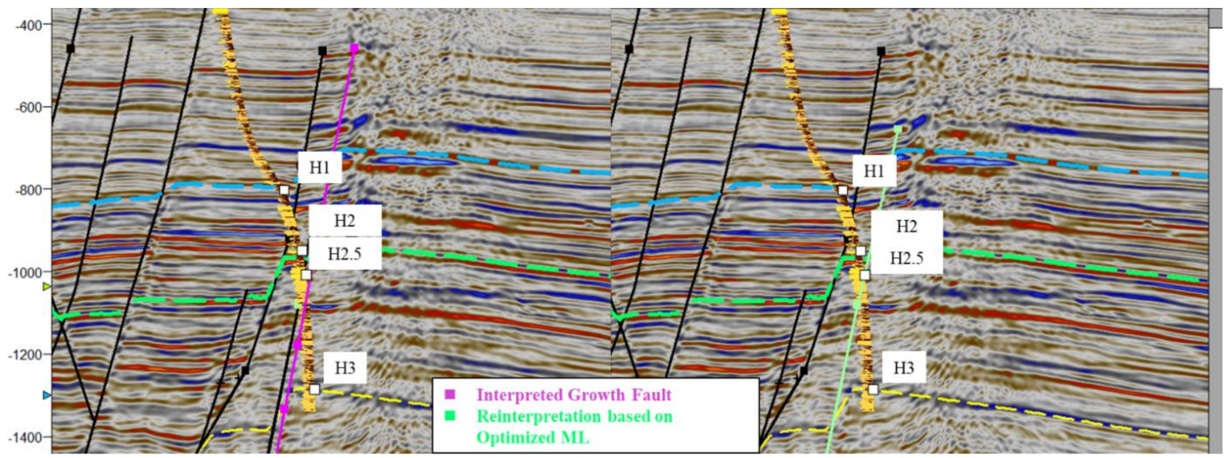

Figure 4: Fault reinterpretation based on the findings of the Optimized CNN Workflow as well as other datasets such as the PS dataset and seismic discontinuity attribute.

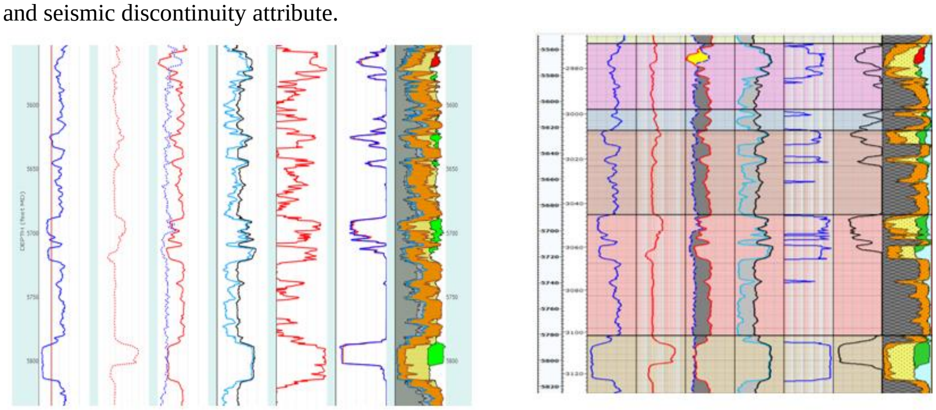

Figure 5: Comparison between the Machine Learning prediction (left) and Conventional Petrophysical Evaluation (right). Results from the test indicates that the results are comparable between the LWD as well as recorded data. Moreover, the result matches well with the conventional approach.