

PS Multi-Frac Stage Selection Criteria for Vertical Wells in Thick, Condensate-Rich, Stacked Tight Gas Sandstones*

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Abstract

The Barik Formation is a tight to low-end conventional gas reservoir in the Sultanate of Oman. It is a series of stacked sandstones which require massive hydraulic fracturing to produce at economic rates. Recent vertical wells have penetrated a thicker section and correlatable shale/silt barriers between which can act as baffles and barriers to vertical stimulation growth. Potentially resources are under-developed and project value is being eroded. The Formation is modelled in one-dimensional Mechanical Earth Models and the hydraulic fracture treatment simulated to model fracture growth and propagation. Radioactive tracer logs are run in key wells to calibrate the stimulation simulation and Mechanical Earth Models to accurately predict the fracture height growth. Through integration of a multi-disciplinary subsurface and stimulation team a strategy to identify where multiple stages may be required is developed using several inputs: the calibrated stimulation models to determine where fracture height growth may be inadequate to stimulate all in place resource; maps of the gas in place for intervals throughout the section to ensure recoverable resource is in place; rock quality (permeability thickness) from petrophysical rock typing; and fluid variation. To maximise value as well as resource recovery, reservoir simulation using the same inputs determines the optimum timing for any subsequent stages over the course of the well's producing life. Consideration of reservoir quality to support production as well as variations in condensate gas ratio are incorporated into the model to determine the point of optimal value for the Operator and the Sultanate.

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Dawson, W.J., G.R. Merletti, D.R. Spain, A. Zett, R. Clark, and J. Hamman, 2015, Integration of Post-Frac Production Logging Data with Pre-Frac Static Petrophysical Description Enhances Reservoir Characterization: Paper OOO.

Spain, D.R., G.R. Merletti, and W.J. Dawson, 2015, Beyond Volumetrics: Unconventional Petrophysics for Efficient Resource Appraisal (Example from the Khazzan Field, Sultanate of Oman): SPE 172920.

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1. Abstract

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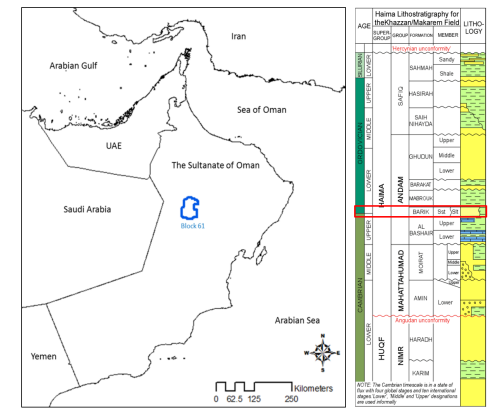
Through integration of a multi-disciplinary subsurface and stimulation team a strategy to identify where multiple stages may be required is developed using several inputs: the calibrated stimulation models to determine where fracture height growth may be inadequate to stimulate all in place resource; maps of the gas in place for intervals throughout the section to ensure recoverable resource is in place; rock quality (permeability thickness) from petrophysical rock typing; and fluid variation.

To maximise value as well as resource recovery, reservoir simulation using the same inputs determines the optimum timing for any subsequent stages over the course of the well's producing life. Consideration of reservoir quality to support production as well as variations in condensate gas ratio are incorporated into the model to determine the point of optimal value for the Operator and the Sultanate.

2. Location

Khazzan commenced development drilling with vertical and horizontal wells in 2014 for first gas production in September 2017.

The main producing interval is the Barik Formation and all wells require stimulation for commercial flow rates.



3. Petrophysical Description and Mechanical Earth Model

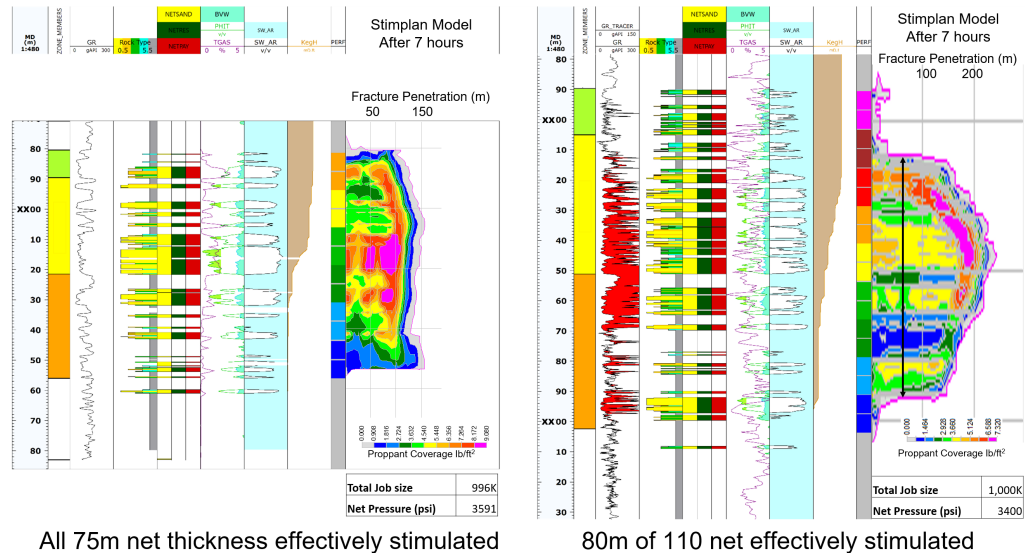
The Barik Formation consists of stacked, tight to low-end-conventional sandstones. The fluid composition as determined through formation tester samples, varies in richness around the block.

The stacking of the sandstones with highly stressed layers between them, means careful consideration of the geomechanical properties must be considered with potential baffles and barriers to vertical stimulation growth.

The reservoir section is binned into petrophysical rock types to reflect the flowing and storage capacity variation and is described in (1) and (2). Previous work (3) has shown the relationship between the petrophysical rock types and in-situ stresses which allows a one dimensional mechanical earth model to be generated for each well. This is the primary input for designing the stimulation.

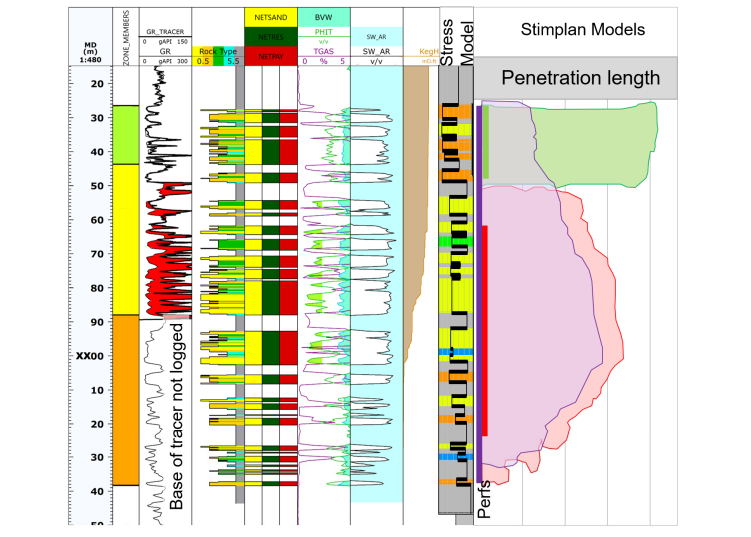
4. Calibration of Stimulation Modelling

BP utilizes stimulation modelling software to simulate massive hydraulic fracture propagation. The primary input is the mechanical earth model derived from the petrophysics workflow. Confirmation of the height growth prediction is performed through tracer logs run in key wells.



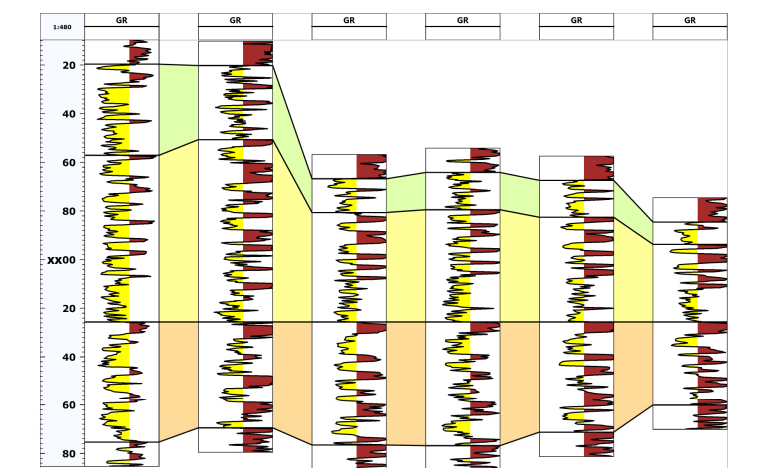
5. Multiple Stage Modelling Considerations

The value of additional half length from shorter perforation intervals is offset against the capital cost of the additional stage. The timing of the second stage also needs to consider the bottom hole pressure and potential for condensate banking.



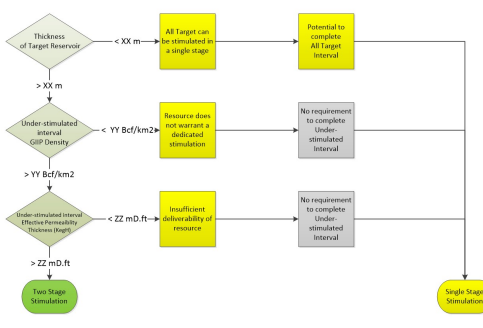
6. Thickness Variation

Thickness variation demonstrates the increased likelihood of ineffective stimulation throughout the net reservoir interval in certain areas. Wells in these areas may require multi-stage stimulation and will be confirmed by well logs.



7. Selection Criteria and Conclusion

A decision tree is proposed to determine where a separate stimulation is required. This ensures the full potential can be realized over the life of the well to maximize value and resource recovery.



8. Acknowledgements

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9. References

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