Role of Geology Operation Facing the Subsurface Uncertainties, in Mitigation, While Drilling and Logging in The Mahakam Delta*

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Abstract

Operation in mature fields in the Mahakam Delta are becoming more complex and challenging. This is due to reservoir connectivity and pressure uncertainty where some reservoirs are already depleted and others might still be under virgin or high pressure conditions, and both conditions could be drilled in the same drilling phase. This can create risks of kicks during drilling, drilling BHA (bottom hole assemble) or wireline tool string stuck during drilling and logging, and a tight drilling window. This complexity is also caused by the distance between the reservoir target and platform being too far which may cause the well bore to become highly deviated. Continuous improvement has been done by Pertamina Hulu Mahakam (PHM), including for pore pressure and geomechanic model. Since 2013, the dedicated in-house pore pressure and geomechanic team has been building support for drilling preparation and operation. Some study has been performed to minimize the uncertainty, such as combination of anamorphous of stress and Eaton calculation to create more accurate shale pressure prediction, methodology to calculate effect of depletion to fracture pressure in reservoirs, digitalization model for quick pressure evaluation and calculations of pump stroke vs. connection gas peak to estimate more accurately the source of ballooning during drilling operations.

With a dedicated integrated geoscience team, the result of prediction has become more accurate due to knowledge and integration between all entities, and can be optimized to create the pore pressure and fracture gradient (PPFG) prediction. This has been shown where drilling problems due to pressure have been reduced and optimized for well design.

Many efforts have also been conducted in data acquisition aspects. For wireline logging operations, improvement for probe type, displacement unit, high tension cable, advance fluid analysis sensor, modification of bottom tool wireline string to allow the tool run smoothly in highly deviated wells, and also cable creep for probe positioning have been implemented in Mahakam Delta fields operations. For mudlogging, some techniques are improving and being optimized, such as constant volume degasser is mandatory for gas out to have accurate gas reading, and gas while drilling (GWD) analysis to support fluid interpretation. All these efforts and continuation for improvements are needed to keep well operations safe, efficient and economic.

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skkmigas PERTAMINA HULU MAHAKAM AAPG

Presentation Outlines

1 | Introduction

2 | Fracture Gradient Estimation

3 | Connection Gas Method

4 | Gas While Drilling

5 | Pressure Test Optimization

6 | Cable Creep Measurement

7 | Conclusions

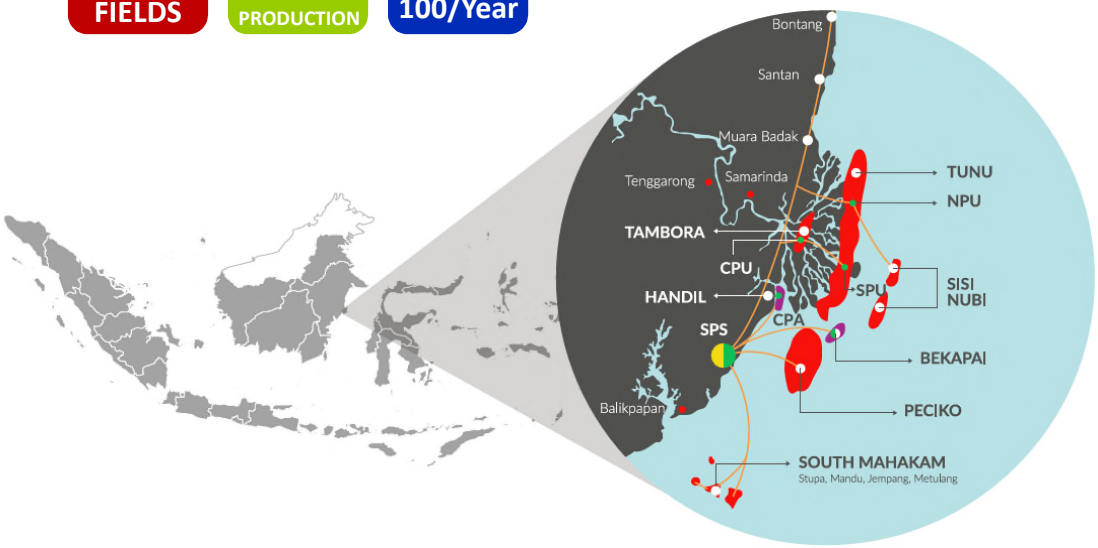
Introduction to Mahakam Delta

GIANT GAS FIELDS

40 YEARS PRODUCTION

>2.000 WELLS DRILLED 100/Year

skkmigas PERTAMINA HULU MAHAKAM



MORE THAN **1.700 km** PIPELINE

103 GTS & CLUSTER

26 PLATFORM

6 PROCESSING AREA

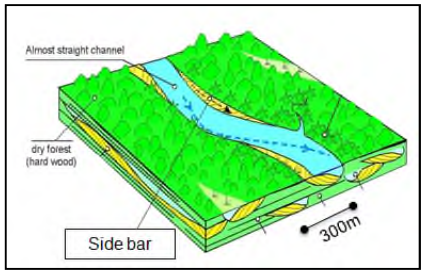
Mahakam Deltaic System

Lower Kutei Basin

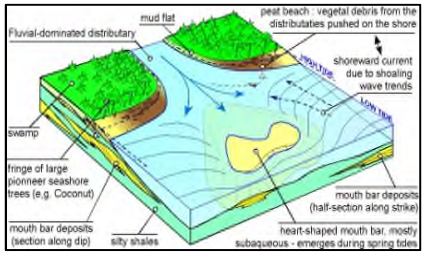
Mid Miocene - Pliocene

Multilayer Reservoir

1. Side Bar - Channel

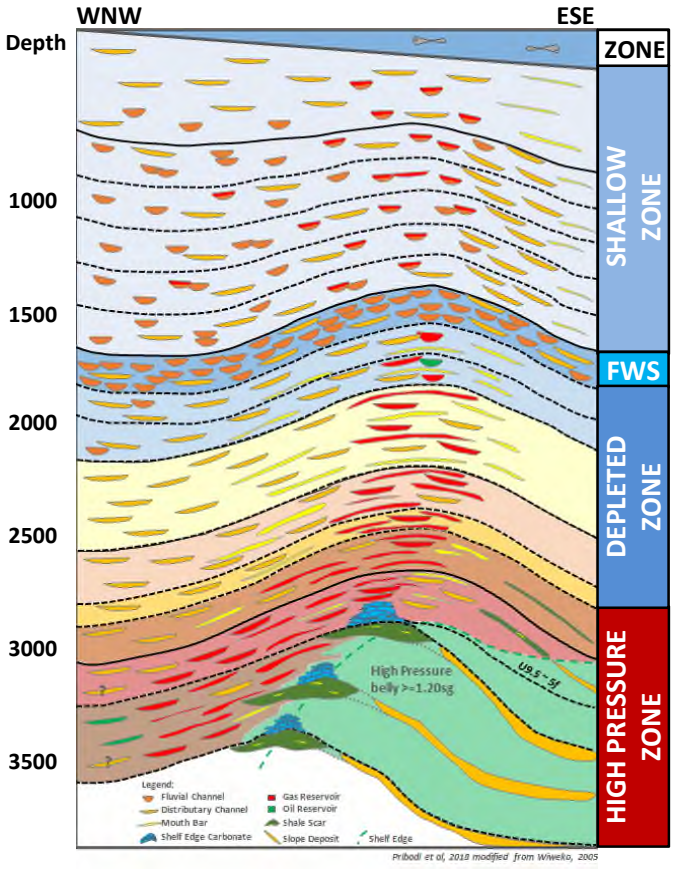


2. Distributary Mouth Bar



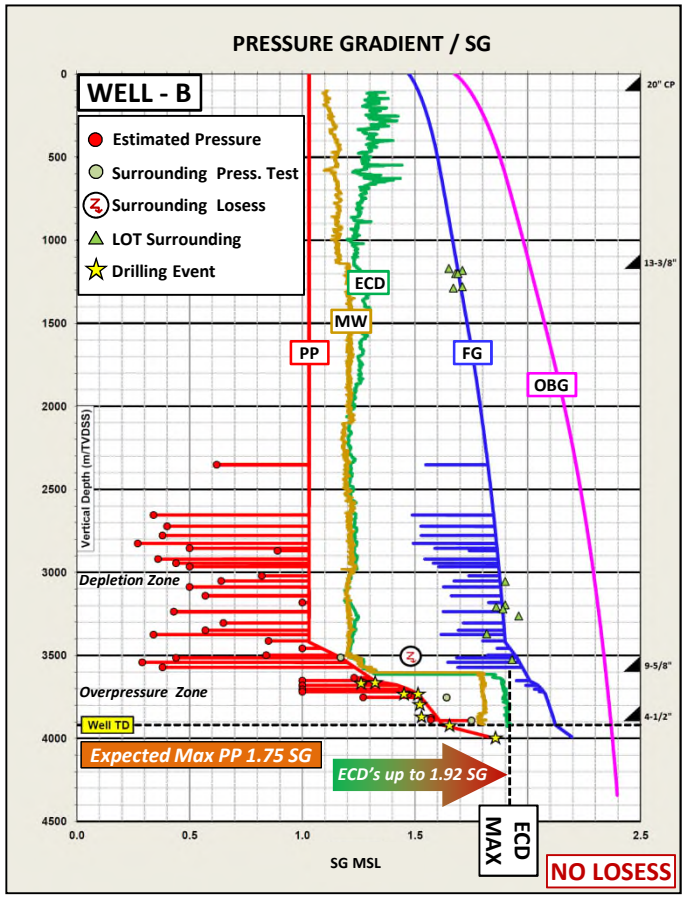
Mahakam Synthesis, 2003

Geology Operation Challenges in The Mahakam Delta



- Marginal Reserves
- High inclination & 3D profile
- Thin Multilayer Reservoir
- Coal Layers (Gas & Pack off)
- Depleted Pressure – Low FG
- Overpressure and Narrow Drilling Window

Pore Pressure and Fracture Gradient Challenges and Solution



Challenges

- **Isolated and Depleted Reservoir Pressure**
- **Reservoir Modeling and Correlation**
- **Fracture Pressure in Depleted Reservoir**

Solution

- **Update Data with Post Mortem Study**
- **Provide Pressure and Fracture Gradient Profile every well that to be drilled (+/- 100 wells/year)**
- **Realtime Pore Pressure – Fracture Gradient Monitoring**
- **Acquire and Update Reservoir Pressure**

Fracture Gradient Estimation Method in Depleted Reservoir

$$P_{frac} = (P_{litho} - P_{pore}) \frac{v}{1-v} + P_{pore}$$

*Fracture pressure calculated by Eaton formula

Mud Losses
Mini Frac
Step Rate Test (SRT)

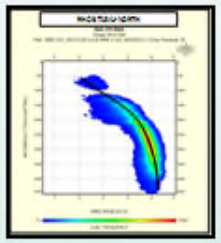
P_{frac}'

$$K = \frac{\sigma_h}{\sigma_v} = \frac{P_{frac}' - P_{pore}}{P_{litho} - P_{pore}}$$

$$v = \frac{K}{1+K}$$

K: ratio horizontal over vertical effective stress

P_{litho}



Overburden Pressure

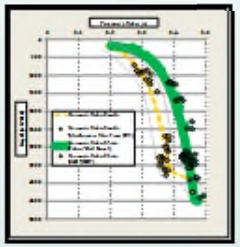
RHOB
(Bulk Density)

P_{pore}

Pore Pressure

Pressure Tests
Drilling Events
Sonic

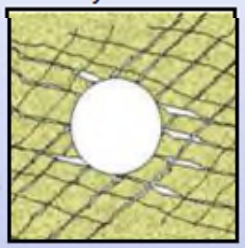
v



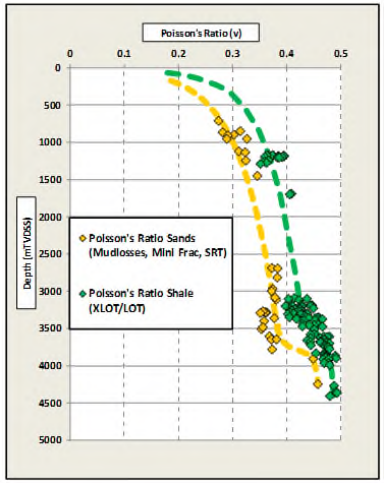
Poisson's Ratio

P_{frac}'
ECD mud losses
Mini-frac
Step-rate Test (SRT)

P_{frac}

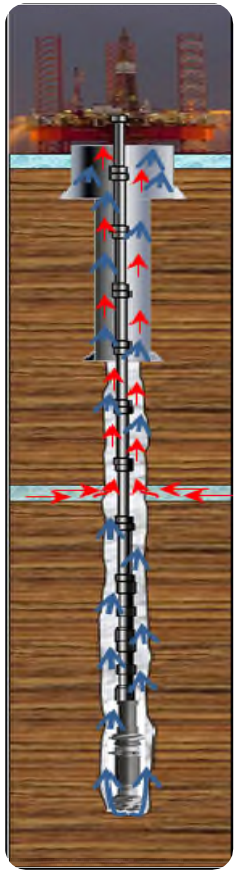


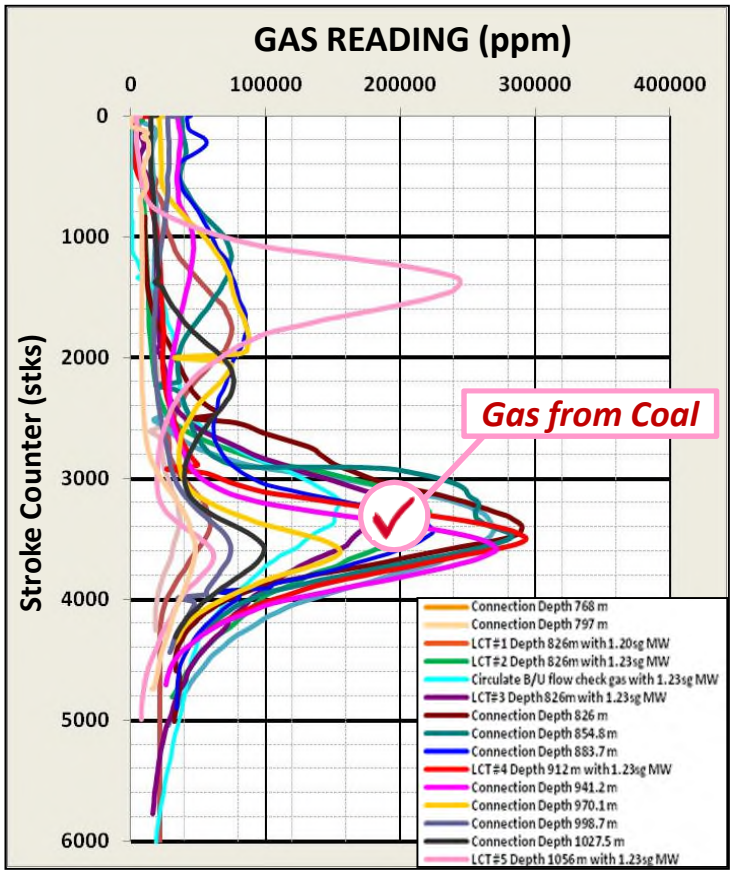
Fracture Pressure



Fadlan et, al., 2016

Pore Pressure Monitoring : Connection Gas Source Calculation





Objectives

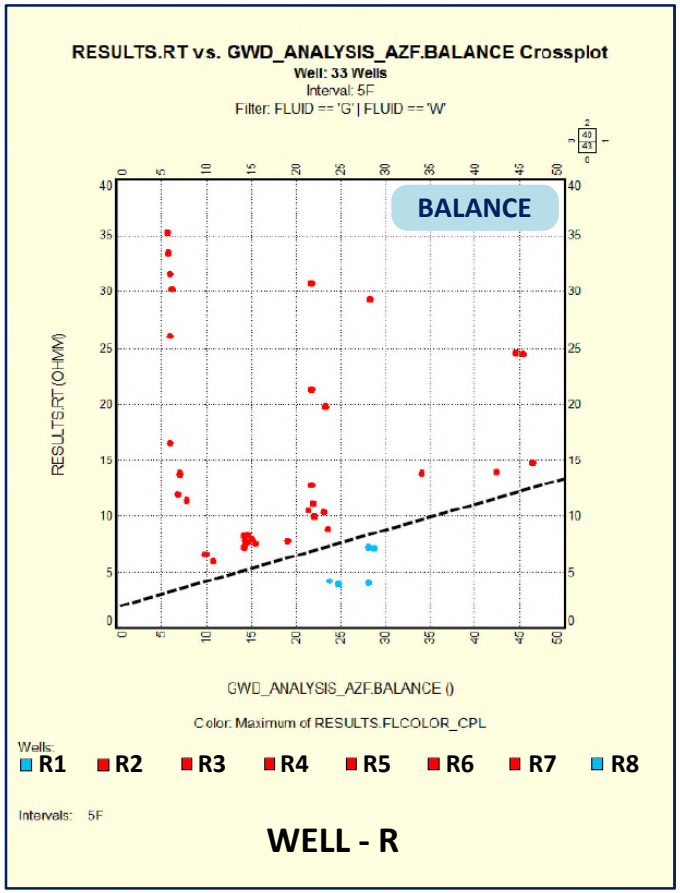
- Identified Peak Gas origin from pump stroke reading
- Differentiate Peak Gas coming from Coal/ Carbonate or Overpressure

Accessing Strategy

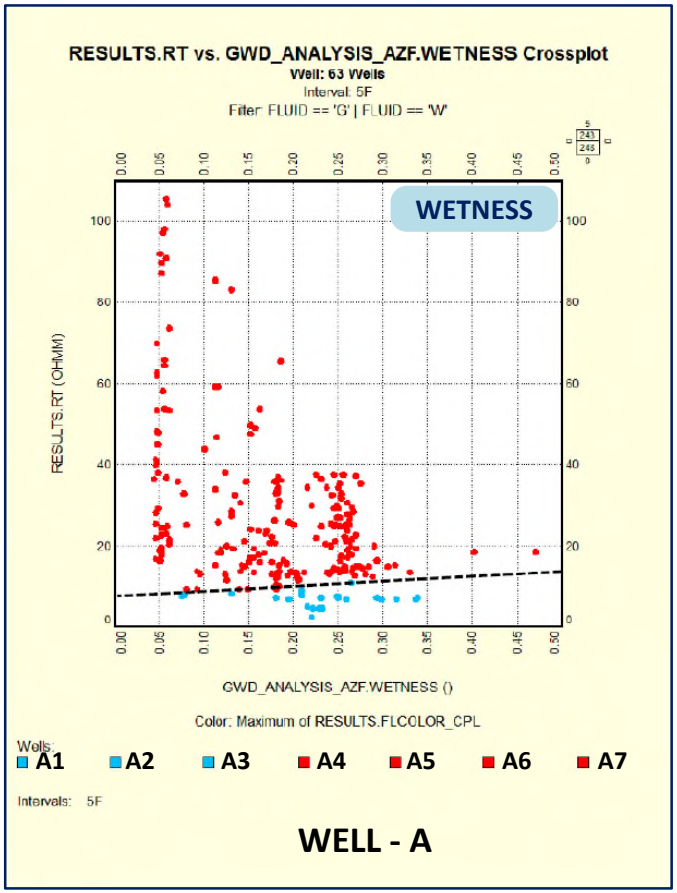
Gas Coming from :

- Coal / Carbonate → Circulate gas
- Overpressure → Increase Mud Weight

Fluid Interpretation : Gas While Drilling



WELL - R



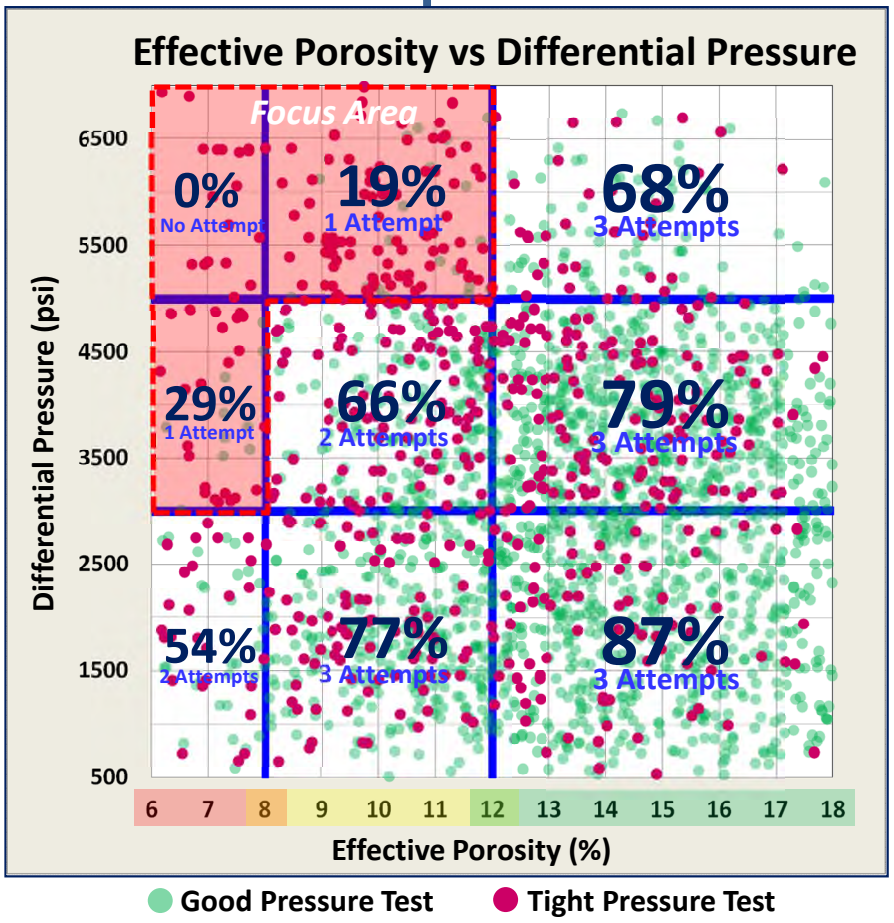
WELL - A

Identified Fluid From Gas While Drilling data

Methodology

- **Depth Match** — *Gas Data – FA – PTR – Perforation*
- **Reservoir Correlation** — *Marker to Marker*
- **Gas Data Quality Control**
- **Gas Ratio Crossplot** — *Define Model*
- **Cut Off** — *Gas and Water Zones*

Pressure Test Optimization : Selecting Point



Back Ground and Objective

35% Tight Result from 2298 Points (2015 – 2018)

Increase Success Ratio of Pressure Test Attempts and Reduce Logging Time

Result

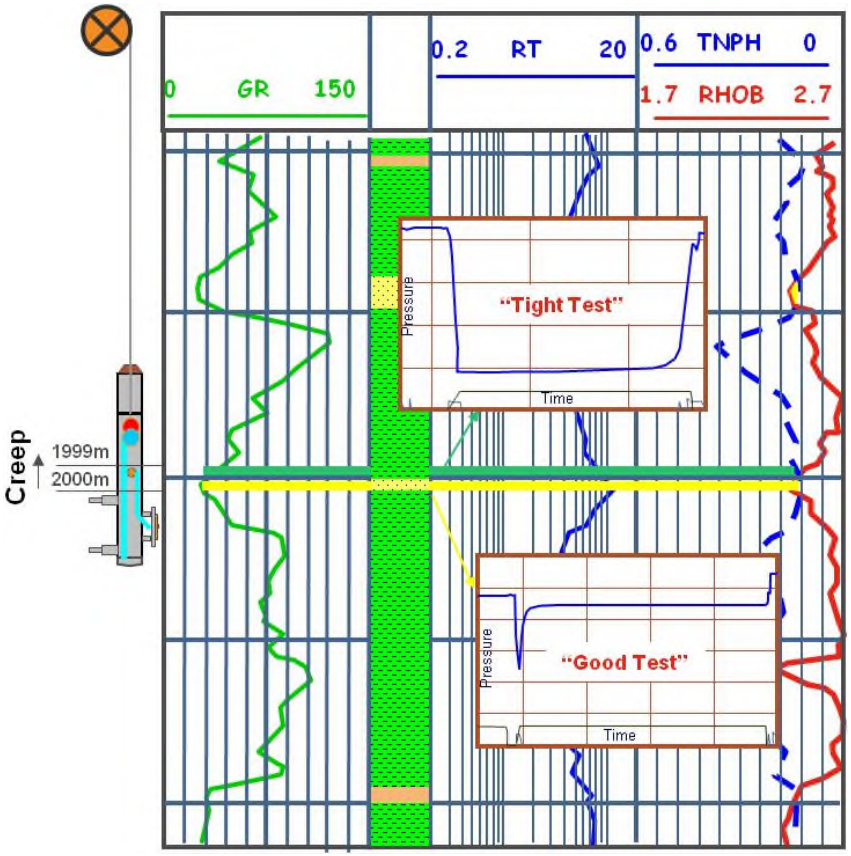
Sandstone Reservoir with :

< 8% Effective Porosity

> 5000 psi Differential Pressure

Are Not Recommend To be Tested

Cable Creep Measurement



Upward movement of tools after the wireline winch stopped due to cable elasticity

- ☑ Optimize pressure acquisition in thin reservoir
- ☑ Less rig time used with less attempt
- ☑ Reduce possibility of tool stuck
- ☑ Reduce packer seal failure

971 REQUEST POINT

2017- 2018 Rig Time Saving

9 MINUTES / ATTEMPT

SUCCESS RATIO BY ATTEMPS

43% before creep

783 SAVE SETS

70% after creep

5 Rig Days Saving

Conclusion

Strategy to facing subsurface uncertainties in Mahakam :

Geology
Operation

Well preparation and mitigation while drilling of depleted reservoirs :

- ✓Improve Fracture Gradient Analysis for drilling optimization, opening drilling window and drill well safely
- ✓An easy and at no cost Connection Gas Stroke Calculation for gas source analysis from coal or overpressure

Logging operation efficiency and success ratio :

- ✓Optimize Gas While Drilling data (no extra cost) to support fluid analysis
- ✓Increase success test in thin reservoir, reduce time & tools exposure with Cable Creep analysis and Pressure Test selection method

Safety

Productive

Efficient