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Reducing Drilling Risks in J bend Wells Targeting Basement in Tectonic Area through Geomechanical Solutions*

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Search and Discovery Article #42308 (2018)**
Posted November 12, 2018

*Adapted from extended abstract prepared for oral presentation, along with the slides presented, given at AAPG Asia Pacific Region GTW, “Pore Pressure & Geomechanics: From Exploration to Abandonment,” Perth, Australia, June 6-7, 2018
 DOI:10.1306/42308Kumar2018

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Introduction

J bend development wells are being drilled in the structurally complex field of North-East India. They are threatened by considerable risk of wellbore instability resulting in severe hole problems which ultimately cause NPT and LIH incidents in the field. For drilling optimization, key is to predict optimal stable mud weight window especially in deviated 8.5” section with deep target sandstone reservoir overlain by different shale formation of varying rock strength and pore pressure in same open section. Figure 1 shows the location of field and wells under current scope of study.

Methods, Procedure, and Process

This article describes how geomechanical information was utilized for the decision-making process and successful completion during J bend well design and drilling operations in Baghjan field. The geomechanical modelling helped select specific mud weights and plan casing points to drill the critical deviated section over the 800m-1000m measured depth. Key drilling risks in each formation were identified, and accordingly mud weights were suggested with additives and BHA type to be used for drilling optimization. A Mechanical Earth Model (MEM) was constructed to represent the state of pore pressure, stress, and mechanical properties of the overburden and reservoir. The model incorporated data from several sources, including open-hole logs, well testing, leak-off tests and drilling records of previously drilled vertical wells. Estimated rock properties and stress profile were subsequently validated using wellbore stability analysis against field observation like caliper, borehole images, stuck pipe, tight hole, kicks and cavings. Sonic compressional velocity and resistivity data have been used to build pore pressure profile and further calibrated with direct pressure measurements.

Figure 2 summarizes drilling issues with formations encountered in this area. Over-gauged hole condition due to shear failures in weak shale layers of Tipam, Barail, Kopili, Prang, Narpuh and Lakadong formations lead to several tight hole/held-up incidents while RIH and POOH.

Results, Observations, and Conclusions

The geomechanical analysis helped to take several critical decisions in the well design: 12.25” for section that should be drilled with 71pcf-73pcf$^+$ to minimize breakouts in shale layers of Barail Formation at 25^o well deviation even formation pressure is hydrostatic. 9-5/8” casing shoe should be set as deep as possible inside Kopili shale to minimize exposure of shale for longer duration. Pore pressure increases from 63pcf to 74pcf inside Kopili Formation, and reversal trend has been observed from Prang Formation to target sandstone Langpar Formation (68pcf-70pcf) (Figure 3). Mud weight needs to be in range of 76pcf-81pcf to minimize breakouts in Kopili Shale layers while drilling at 30^o well deviation. Differential sticking incidents are evident in permeable sandstone due to thick mud cake formation based on offset wells, and hence fluid loss needs to be maintained while drilling J bend well. Depending on well azimuth, mud weight can vary 3pcf-4pcf due to minimum and maximum horizontal stress contrast.

Figure 4 shows the variation of Unconfined Compressive Strength (UCS) in shale and sandstone. The decrease in UCS in shales corresponds with the failure seen on the caliper.

Understanding from Analysis of Offset Wells

- UCS values are relatively low in shales in the Barail, Kopili, Prang, Narpuh and Lakadong formations, which correspond to the over-gauged condition seen on the caliper (Figure 5).
- Tight hole and tool stuck incidents are prominent in Kopili shales, Barail shales, Prang and Lakadong.
- Formation pressure is hydrostatic above Kopili but increases from 63pcf to 74-75pcf in the Kopili Formation. Below Kopili, there is a pore pressure reversal trend from Prang to Langpar (69pcf-70pcf).
- The stress regime is normal faulting.
- Sensitivity analysis of stable mud window for different formations is shown in Figure 6.
- With higher well deviation, shear failures will be observed in weak shales with lower stable mud-weight limit. As tight-hole and tool-stuck incidents are prominent in Kopili shales, Barail shales, Prang and Lakadong, proper hole cleaning with appropriate mud chemical composition should be used to reduce fluid invasion in sand to avoid differential sticking and minimize time-dependent shale instability.
- Mud weight of 76-81pcf should be used while drilling deep below overpressured Kopili Shale down to basement for avoiding shear failure at higher well deviation. However, it would create extra overbalance against lower pressure sandstone reservoir. This will need enhancement of mud chemical properties to reduce filter cake thickness.
- Mud weight of 70-73pcf should be used while drilling Tipam and Barail.
- 9 5/8” casing should be set deep at Kopili Shale to have higher LOT.

Impact and Recommendations for Future Wells:

Although early vertical wells had suffered similar wellbore instability incidents, the J bend wells engineered with the geomechanics information and better hole cleaning were drilled from surface to TD without major drilling incidents. Daily drilling reports were reviewed with drilling parameters and shaker's pictures to recommend mud weight and feasible drilling practices for POOH/RIH. It helped to save almost 5-7days as compared to planned schedule. Mud weight was kept on relatively lower side with proper hole cleaning measures to minimize risks of differential sticking. Figure 7 shows basic logs for the following wells.

Well-A: 76pcf $^{+}$at well TD   ($^{+}$1.0 SG=63pcf=8.34ppg)
Well-B: 76pcf at well TD
Well-C: 73pcf-76pcf (1.22 SG)
Well-D: 73pcf-78.5pcf (1.25SG)
Recommended based on geomechanics: 76pcf-81pcf for "weak" shale

Kopili Shale has ovalized hole condition due to lower mud weight being used, however, for deeper reservoir layer, hole condition is better. There is further scope to improve drilling with further chemical stability study of Kopili Shale with WBM optimization. Considering presence of structural discontinuities, 3D study has been proposed to cater stress changes and lateral variation of rock properties.

Selected References

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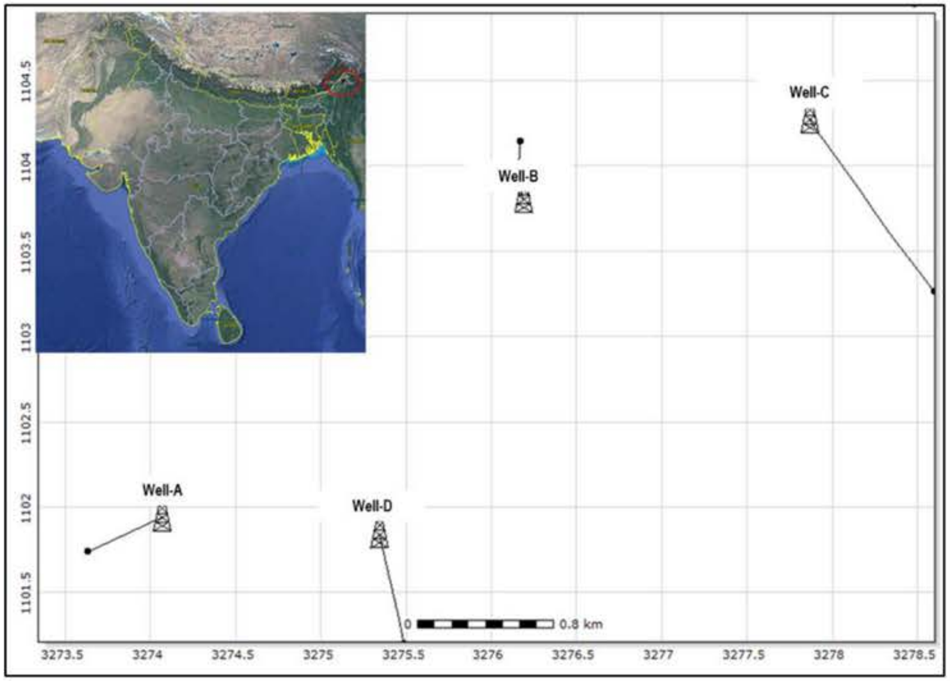
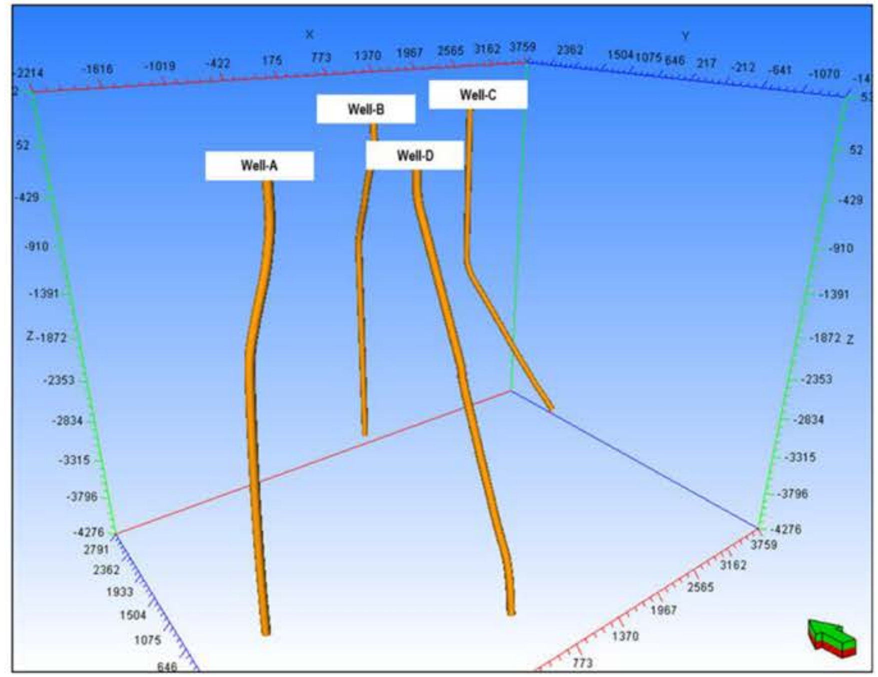


(a) Location of wells considered under the study



(b) Well profiles

Figure 1. Location of wells considered and their trajectories.

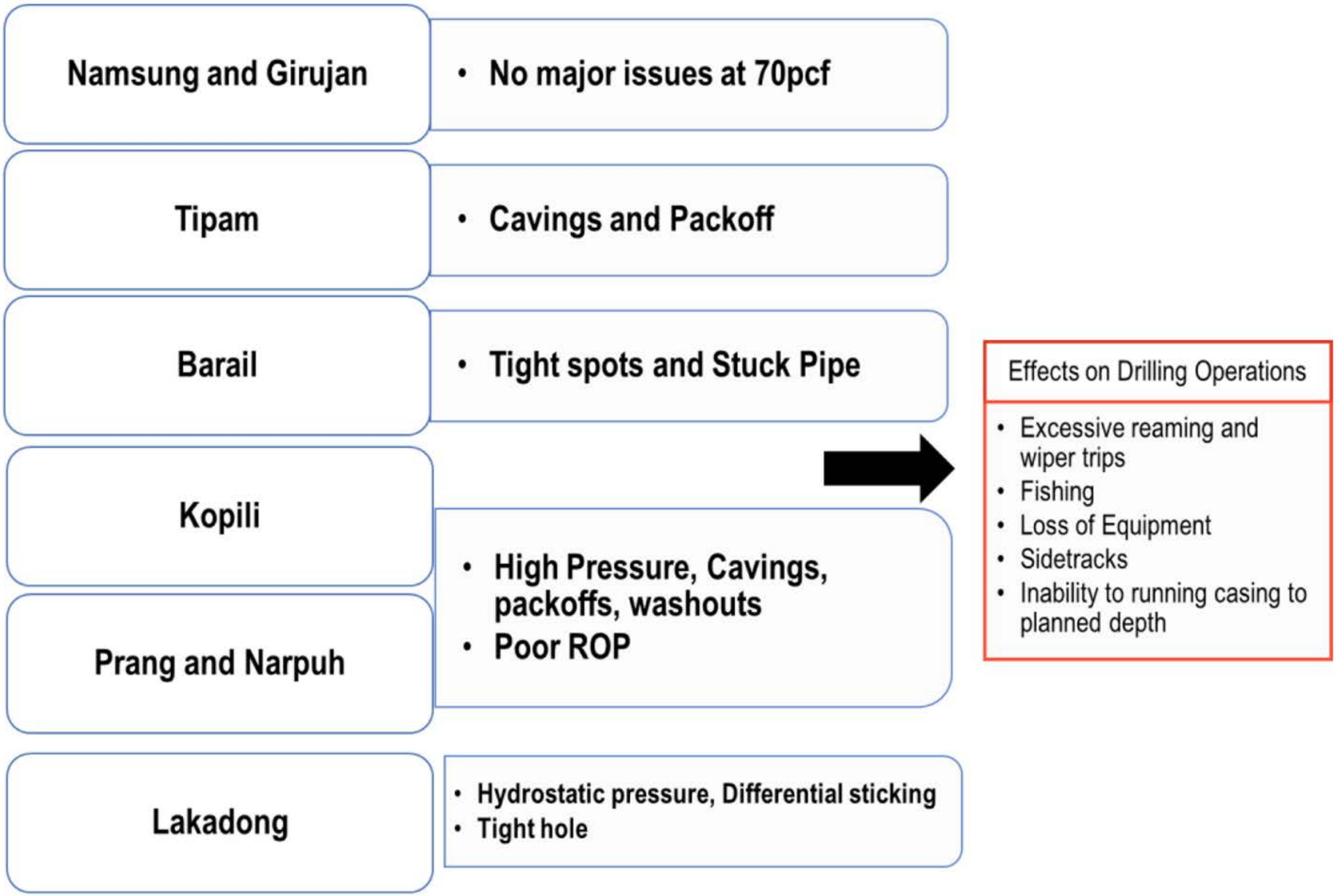
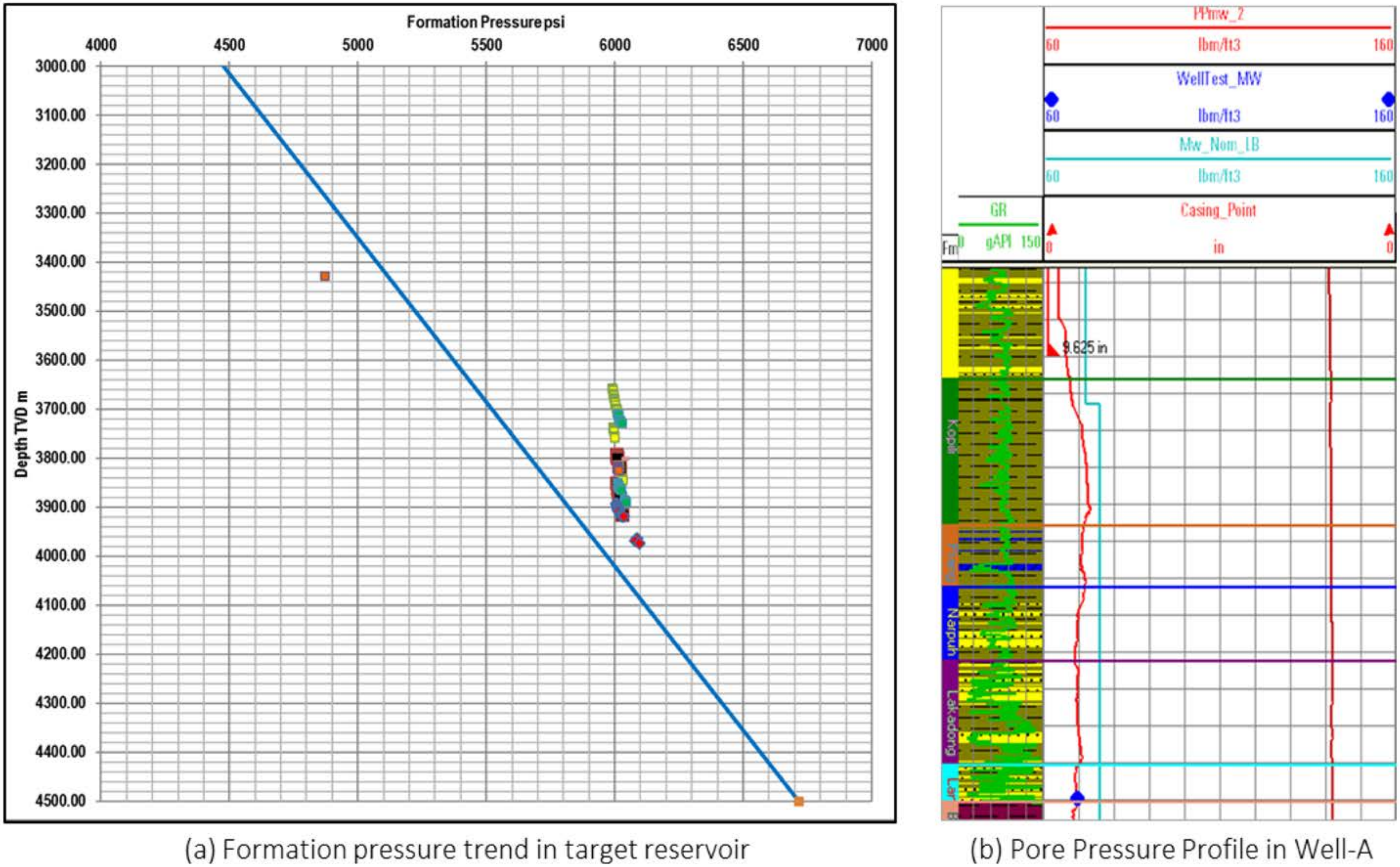


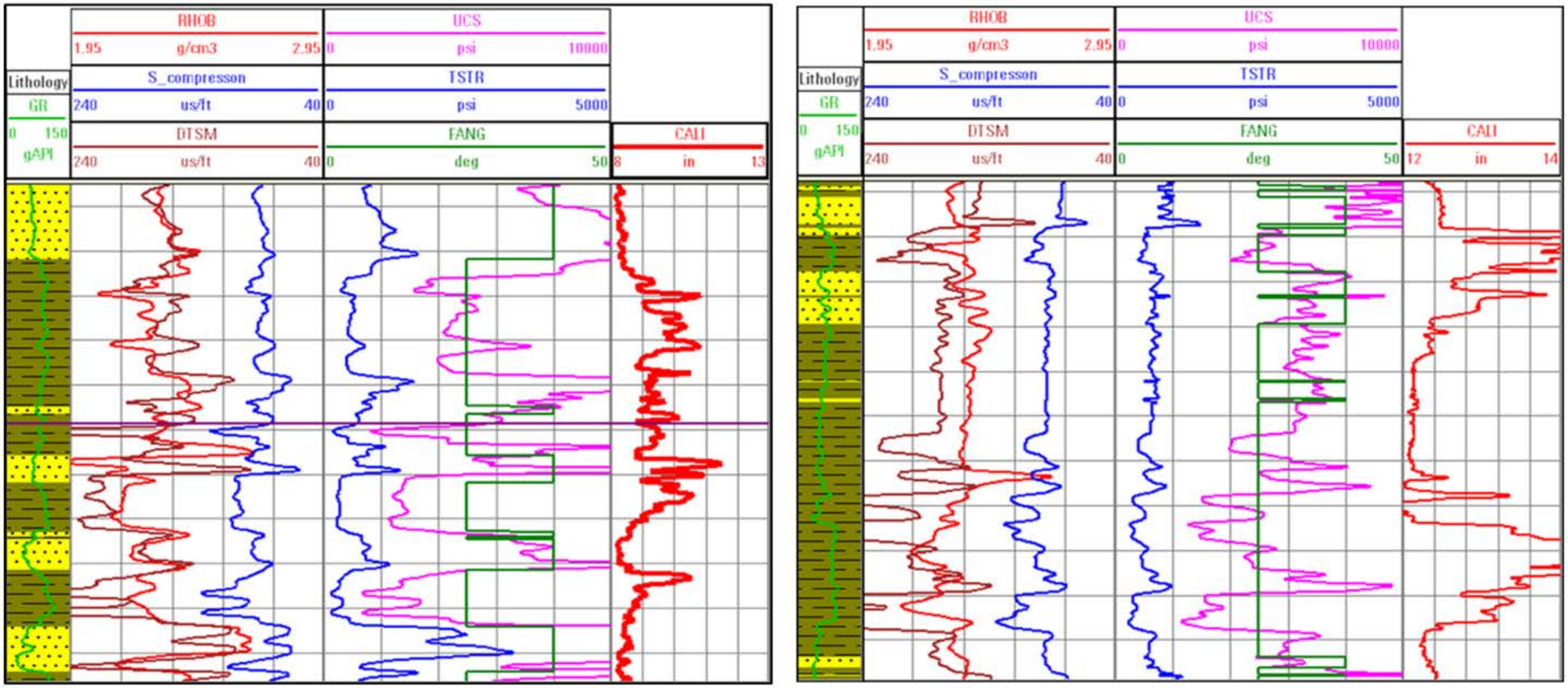
Figure 2. General lithology and drilling issues associated with them.



(a) Formation pressure trend in target reservoir

(b) Pore Pressure Profile in Well-A

Figure 3. Variation of pore pressure profile across the field and along the well-A. Formation pressure is hydrostatic above Kopili but increases from 63pcf to 73-74pcf in the Kopili Formation. Below Kopili, there is a pore pressure reversal trend from Prang to Narpuh (69pcf-70pcf).



Variation of Rock Strength in Narpuh and Lakadong formation

Variation of Rock Strength in Barail formation

Figure 4. Variation of uniaxial compressive strength(UCS) with sandstone and shale lithology.

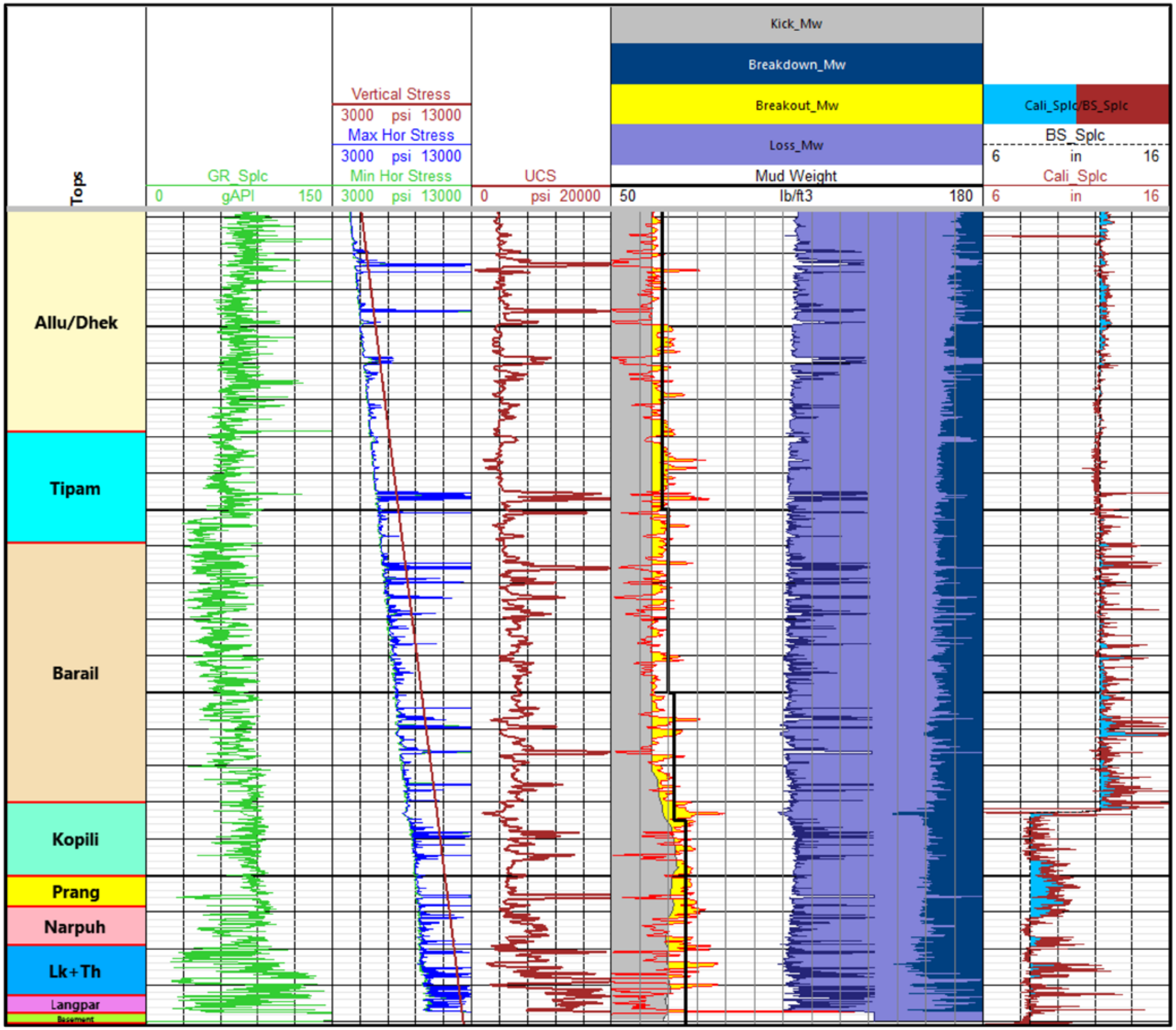


Figure 5. Stable mud weight window, with Gamma-ray, Stresses, UCS, and caliper for Well-A.

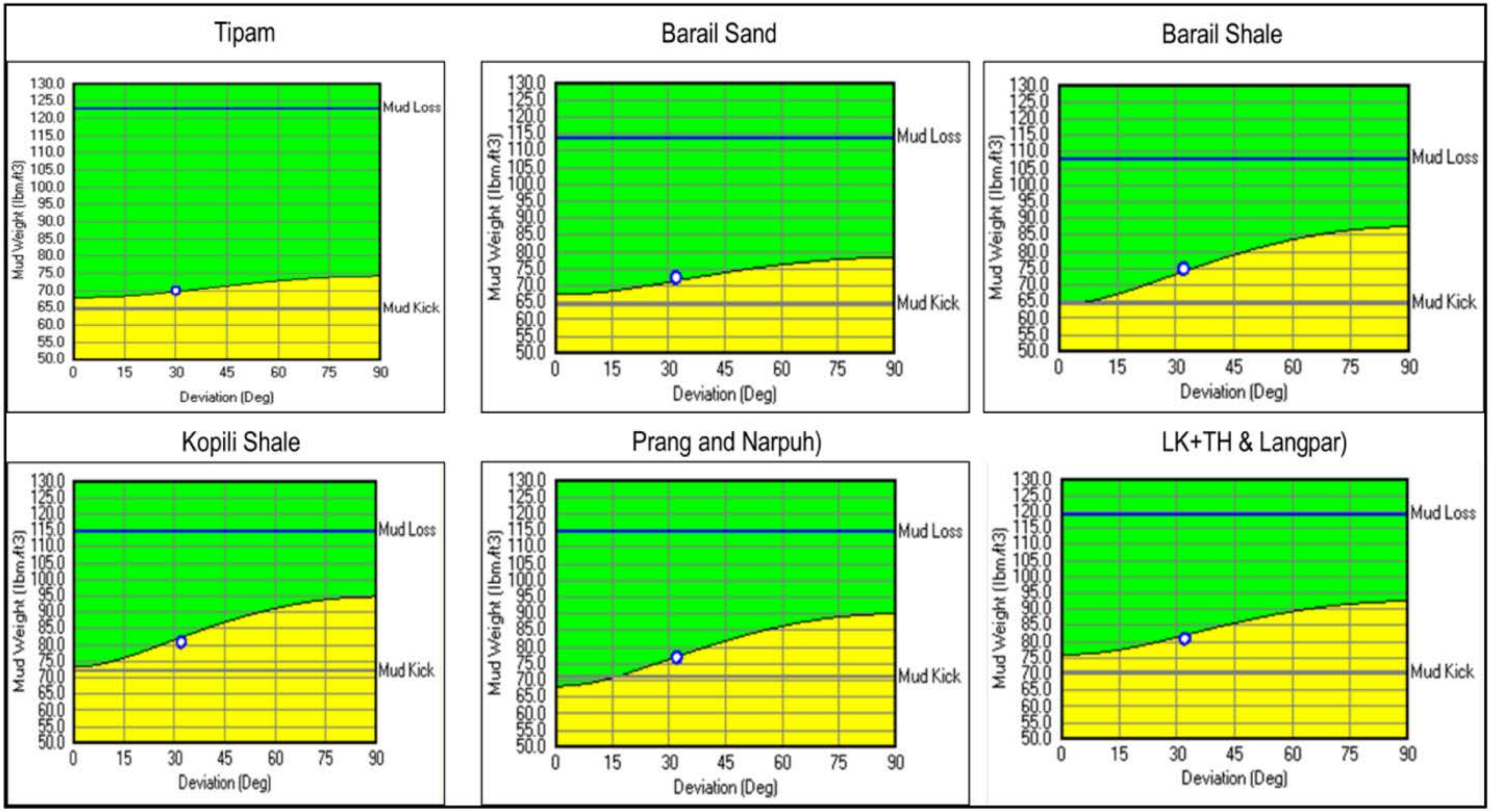


Figure 6. Sensitivity analysis for different formations.

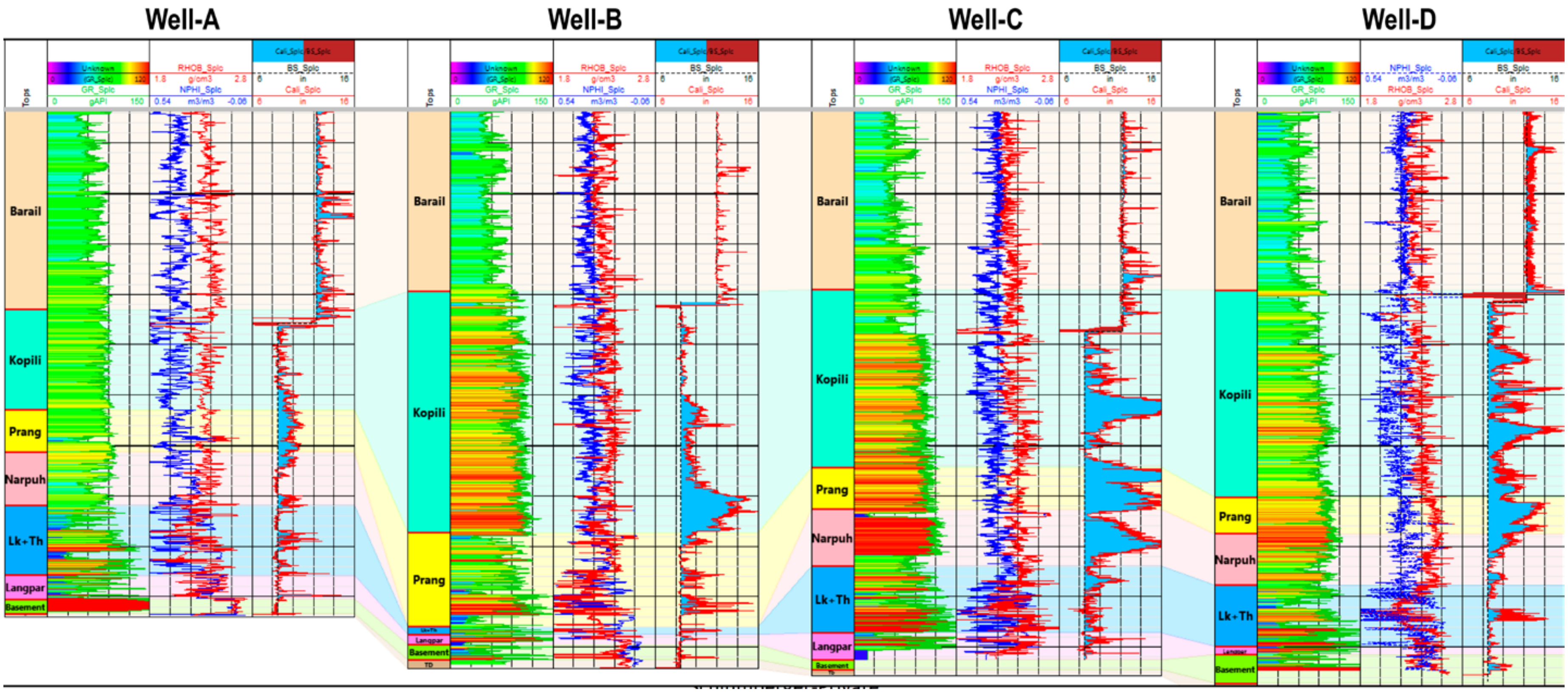


Figure 7. Basic logs (Gamma-ray, Bulk Density, Thermal neutron porosity, and Caliper) for wells in field.

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