Anisotropic Geomechanical Analysis to Identify the Loss Prone Zones for the Completion of HP HT Well - A Case Study from KG Onland, India

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ABSTRACT

Deep wells are drilled down to 4000 m to 4600 m in true vertical depth (TVD) on the onland KG-Basin having target of upper Jurassic to lower Cretaceous sandstone formations. Basalt flows, fractured sandstones, tightly cemented siltstones, pyritic shales, abnormal pressures, and complicated transverse isotropic layers test the limits of well construction and engineering design at high-pressure, high-temperature (HPHT) conditions. Traditional prognosis methods fail to identify the loss prone zones & to predict the abnormal pore pressure regimes and stress anisotropy created by the disturbed tectonic history and complex geological setting.

This case study presents one of many success stories where Geomechanics and Wellbore Stability pre-modelling and proactive decision making driven by real time Geomechanical contributions helped in identifying the loss prone zones & their isolation and drilling a deep HPHT borehole (Well-B) through a low porous & permeable clastic reservoir in one of the oil and gas fields in the KG onshore.

During drilling of Well-B; multiple drilling complication were faced such as unpredictable well flow events and wellbore instability, losses, cavings, tight pulls, breakouts and equivalent circulating density fluctuations. Apart from the drilling and completions challenges, the wellbore instabilities affected openhole logging and completion operations, leading to inadequate formation evaluation.

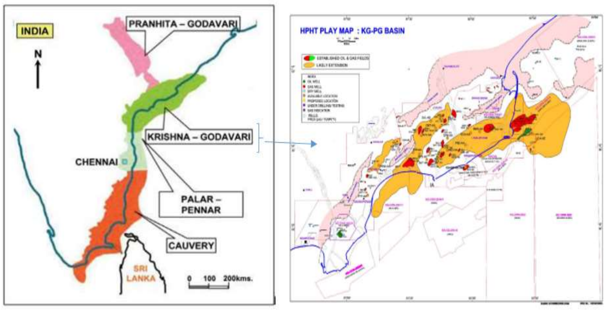
An anisotropic Mechanical Earth Model (MEM) was built using both horizontal and vertical elastic properties to estimate an accurate stress profile that can predict the mud loss zones and completion quality. High risk zones were flagged inside the R-Formation for mud loss and look-ahead safe mud weight window was prepared for the R-Formation & N-Formation.

In this paper we present an integrated approach to using Geomechanical analyses for determining the loss prone zones, stable mud-weight window, and successful completion of the well.

INTRODUCTION OF THE AREA

There are many HPHT reservoirs in India that currently lie untapped. Krishna Godavari basin is a proven petroliferous deltaic basin formed by discharge of two large rivers Krishna and Godavari flowing on east coast of India. Maximum deposition thickness found in this basin is up to 6KM with paleontological evidence suggesting period of slow deposition and subsidence. Krishna Godavari Basin is a peri-cratonic passive margin basin on the east coast of India.

The Indian Sub-Continent has one of the few HP-HT belts of the world. The eastern-offshore and surrounding belts have acreage of such nature. Amongst the above, the KG-PG basin has been a cradle of many deep-seated HP-HT wells. Upper Jurassic to Lower Cretaceous syn-rift



Map showing HPHT-PLAY KG-PG Basin(Year:2016)

Figure:1

sandstone encountered in of KG Basin have been deposited during the early to late rift climax stage mainly driven by mass gravity flows down the basin bounding fault escarpment with some amount of lateral reworking. These reservoirs have undergone considerable compaction as well as higher order of diagenesis hence are tight, and at present under HT-HP environment.

B-Field is one of the HPHT Field located in KG basin with proven Oil & gas reserves in R-Formation & N-formation which belongs to late Jurassic to early cretaceous age. N-Formation is a low porosity and low permeability reservoir. Upper R-Formation shale lying on the N-formation is sticky in nature. 12 ¼" & 8 ½" open hole sections of these wells are drilled through R-and N-Formations. R and N Formations are lying in the temperature range of 280-380degF and static bottom hole pressures of 7500-14500psi. These reservoirs are having low porosity (6-9%).

Wells being drilled in this field through these formations are experiencing severe drilling challenges which include losses, drill string stuck-up, frequent held ups, tight pulls etc. Due to these complications basic logs like Gamma Ray-Resistivity-Density-Neutron-Caliper logs were only recorded in the offset wells. Advanced sonic measurements are not available in this field.

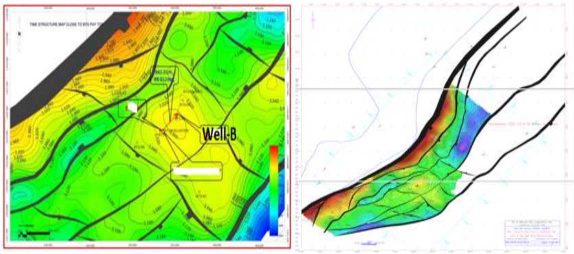


Fig: Time structure Map of B-Field Pay

Structure Map Close to N-Formation Top of B-Filed

Figure:2

CHALLENGES;

Deep wells are being drilled down to 4000 m to 4600 m in true vertical depth (TVD) on the onland KG-Basin having target of upper Jurassic to lower cretaceous sandstone formations. Basalt flows, fractured sandstones, tightly cemented siltstones, pyritic shales, abnormal pressures, and complicated transverse isotropic layers test the limits of well construction and engineering design at high-pressure, high-temperature (HPHT) conditions. Traditional prognosis methods fail to identify the loss prone zones & to predict the abnormal pore pressure regimes and stress anisotropy created by the disturbed tectonic history and complex geological setting.

Previous wells in the region have been plagued with significant NPT because of wellbore instabilities during drilling, incomplete log data acquisition, and poor-quality primary cementation.

Key challenges in the field have been:

- Unstable hole condition caused by shale breakouts, abnormal pressures, and borehole drift
- Offset well experience of poor cementing in intermediate and production sections
- Challenging and inconclusive well testing experience in offset wells
- High-stress regime and compromised well integrity
- Stuck-pipe incident and frequent tight pulls and caving's

To ensure risk-free further drilling and completion of well B, an advanced Geomechanical analysis, incorporating the effect of intrinsic anisotropy, was performed in one phase. The 12.25-in. anisotropic MEM was built to accomplish the following:

- To identify the loss prone zones
- Optimize hydraulics for 9.625-in. casing and cementing with minimum fluid losses
- Provide a look-ahead safe mud weight window based on Geomechanical analysis to drill further 12.25-in section & 8.5-in section

BRIEF HISTORY OF THE WELL-B & SEQUENCE OF EVENTS BEFORE ADVANCED ACOUSTIC LOGGING;

The case study well: Well-B; Released as an exploratory inclined well (L-Profile) with an objective to probe and delineate B-field-3 equivalent pays within Gollapalli Formation. Planned TD: X782,(MD)/X600m(MSL). Expected BHT at TD: 375-385 degF.

In this well 17.5-in section was drilled upto Z480m & Resistivity-Sonic logs were recorded (BHT: 208degF).

12.25-in section was drilled upto X514m with Telescope-GR service (Section TD: X900m & 13.375-in casing shoe was placed at X481m) (Deviation: 29.40 deg at X441.27m/X366m; KOP: Z520m) (SOBM mud system).

Drilled the well upto X545m (12.25-in section with SOBM mud system). Continuous Loss & gain was observed during drilling.

GEOMECHANICAL STUDY TO IDENTIFY THE LOSS PRONE ZONES & LOOK-AHEAD:

Losses, well flow and several tight pull/ held up have been reported in 12 ¼" section, and multiple instances of tight pull/ held up and stuck pipe was reported in 17.5" section of the well. To minimize these drilling related risks in future wells of same block of the field, advanced sonic logging along with cement bond logging has provided an integrated solution in the form of pore pressure, stress regimes, rock mechanical properties and stable mud weight window for well based on recorded advanced Sonic measurements including post-drill Mechanical Earth Model (MEM) of well-B. Acoustic based Geomechanical analysis has been conducted for successful well delivery & identification of Loss prone zones.

Recorded advanced sonic measurement log along with resistivity log in the interval 2428-3305m was recorded to analyse the Loss Zones & look ahead for further drilling & completion.

Mechanical Earth Modelling with Advanced Acoustics for Geomechanical Analysis;

Geomechanics Workflow:

The basic approach to Geomechanical analysis is to use the available data for interpretation of rock strength, stress and pressure to construct a Mechanical Earth Model (MEM). Based on MEM, mud weight window was constructed, and mud weight was recommended for future drilling depending on well azimuth and deviation. Below Figure illustrates a typical workflow for MEM.

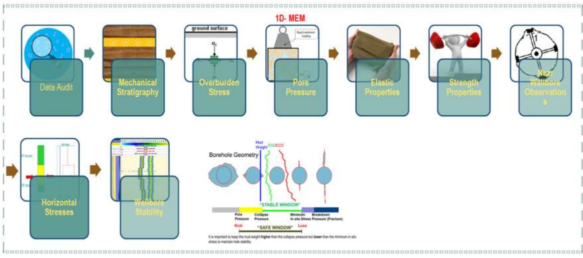


Figure . A typical workflow for MEM construction

Figure:3

Concept of Wellbore Stability Analysis & Stress inversion:

The initial state of existing compressive stress in the rock formation can be resolved in three components: vertical stress (σv), minimum horizontal stress (σh), and maximum horizontal stress (σH). As the well is drilled, stress redistribution takes place near the wellbore wall with replacement of the initial support of drilled out rock by mud pressure. The redistributed stresses can be resolved in form of hoop stress acting circumferentially along wellbore, the radial stress and the axial stress acting parallel to the wellbore axis. With well deviation, the additional component of shear stress comes into play. If the rock strength is enough to sustain redistributed stresses, in either compression or tension, the wellbore will remain stable with the present mud weight.

Wellbore Stability Analysis (WBS) is a methodology to check the validity of a Mechanical Earth Model (MEM) comprising of rock mechanical properties and stress profile. MEM based predicted borehole failure (losses, breakouts, tensile induced fractures, etc.) is checked against the actual drilling events observations, breakout or tensile induced fractures observed on caliper or image logs. In case of a discrepancy, strain parameters and/or estimated UCS parameter are modified to obtain a better history match.

In the absence of borehole images or complex wellbore failures, advanced acoustic measurements 3D Shear velocity radial profiling provides valuable insight. The far field shear velocities can be used to interpret anisotropy due to natural features whereas, the near wellbore shear velocities can be used for near wellbore alteration or skin due to hoop stresses.

In this study, a poro-elastic horizontal strain model (Fjaer et al., 1992) is used to estimate the magnitudes of the minimum and maximum horizontal stresses. This technique does not pre-determine or pre-conceive the order of the in-situ stresses but instead allows the convergence towards estimates of stress magnitudes (and hence stress regimes) that are driven by the available log and well data. The method applies poro-elastic theory to the long-term sedimentation and deposition of formations buried deep below the ground's surface, accounting for lateral spreading and/or horizontal compression via strains that may occur in the horizontal stress directions. Hence, the two strains, εh (in the Minimum Horizontal Stress direction)
and εH (in the Maximum Horizontal Stress direction) can be used as calibration factors to match the above stress model to the current state of stress in the ground.

From this approach, we obtain

$$\sigma_h = \frac{\nu}{1-\nu}\sigma_v - \frac{\nu}{1-\nu}\alpha P_p + \alpha P_p + \frac{E}{1-\nu^2}\varepsilon_h + \frac{\upsilon E}{1-\nu^2}\varepsilon_H$$

$$\sigma_H = \frac{\nu}{1-\nu}\sigma_v - \frac{\nu}{1-\nu}\alpha P_p + \alpha P_p + \frac{E}{1-\nu^2}\varepsilon_h + \frac{\upsilon E}{1-\nu^2}\varepsilon_H$$

Sedimentary rocks in the subsurface have intrinsic anisotropy associated to the grain and texture. Often shale layers exhibit anisotropy due to their finely layered texture (TIV anisotropy). Similarly permeable formations such as sandstones or carbonates show stress related anisotropy or anisotropy due to natural fractures (TIH anisotropy). In presence of TI anisotropy, poro-elastic stress model is modified to consider the anisotropy in horizontal and vertical rock elastic properties. The anisotropy effect on Horizontal stresses is captured in the equations below.

$$\sigma_h = \frac{E_h}{E_V}\cdot\frac{v_V}{1-v_h}\cdot(\sigma_V - \alpha_V\cdot p_p) + \frac{E_h}{1-{v_h}^2}\cdot(\varepsilon_h + v_h\cdot\varepsilon_H) + \alpha_h\cdot p_p$$

$$\sigma_H = \frac{E_h}{E_V}\cdot\frac{v_V}{1-v_h}\cdot(\sigma_V - \alpha_V\cdot p_p) + \frac{E_h}{1-{v_h}^2}\cdot(\varepsilon_H + v_h\cdot\varepsilon_h) + \alpha_h\cdot p_p$$

σh = Minimum Horizontal Stress, σH = Maximum Horizontal Stress, σV = Overburden Stress
α = Isotropic Biot elastic coefficient, αV & αh = Anisotropic Biot's constants
E = Isotropic Young's Modulus, EV & Eh = Vertical and Horizontal Young's modulus respectively
ν = Isotropic Poisson's Ratio, νV & νh = Vertical and Horizontal Poisson's ratio respectively

Pp = pore pressure
εh = Strain in Minimum horizontal stress direction
εH = strain at Maximum horizontal stress direction

The 3D shear velocity radial profiling data from the advanced acoustic measurements can be used to invert the Minimum and Maximum Horizontal Stresses (Sinha et. al, 2006 & 2009) and invert TI anisotropic elastic properties and acoustic anisotropy parameters (Donald et. Al. 2018). The TI anisotropy data provides the necessary inputs to get reliable estimates of anisotropic elastic properties.

Direct horizontal stress calibration values have been estimated using integrated stress analysis with advanced acoustic measurements data as explained in Figure below. This helped to calibrate horizontal strain values in above equations. Final stress profile obtained after history matching process & utilizing advanced acoustic measurements Radial profiling data is shown below. Detailed algorithm has been provided in reference paper - SPE-95841.
The invariable advantage of the above methodology is the minimal dependence on external calibration data in wild-cat exploratory situations and a robust MEM for timely applications.

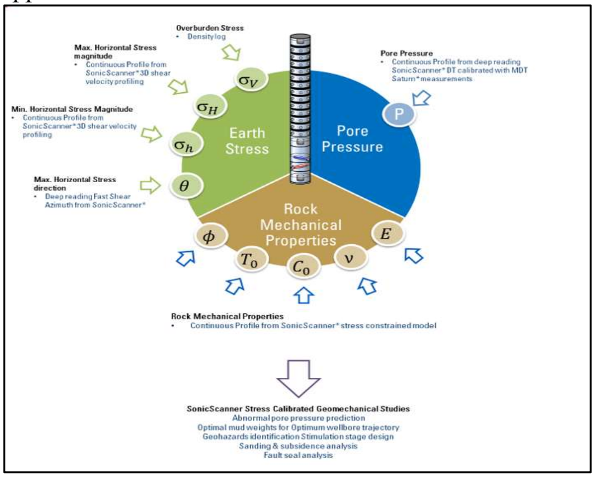


Figure:4

Fig:Integrated stress analysis using advanced acoustic measurements (SPE-11089)

Elastic properties of transversely isotropic (TI) formations are estimated using advanced acoustic measurement data. Regional stress regime is likely to be Normal faulting regime. Drop in stresses has been seen in sand layers and in some weak shale intervals (Thomsen Gamma Negative). Increase in stresses is seen in clay dominating formations (Thomsen Gamma Positive). Anisotropic stress model

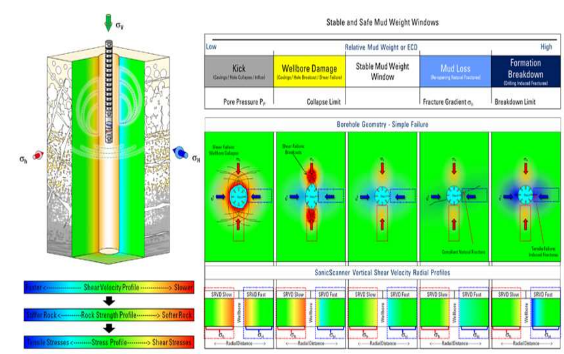


Figure Validation of Mechanical Earth Model Using Wellbore Stability Analysis and SonicScanner Shear Velocity Radial Profiles

Figure:5

suggests a dominantly normal faulting regime with high stress layers in between. Below Z920 m alternating weak and strong layers can be seen.

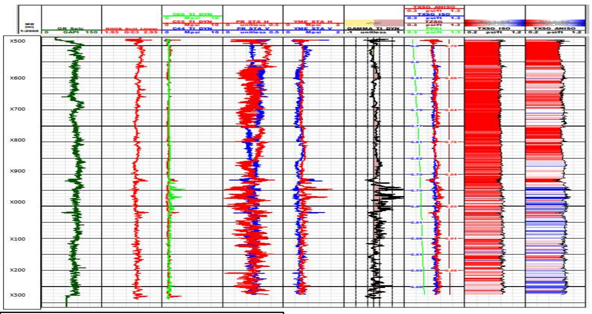


Figure:6

Well-B – Isotropic vs. Anisotropic Stress profile & Mechanical Properties from Advanced acoustic measurement analysis

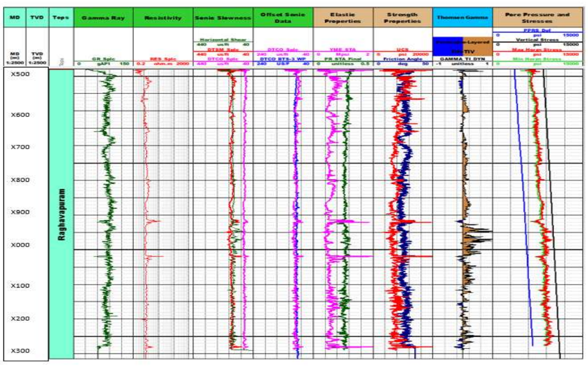
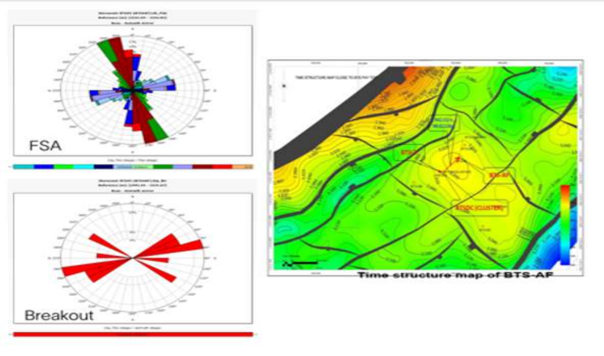


Figure:7

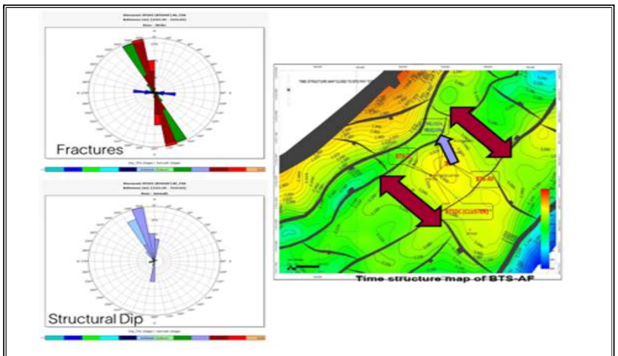
Figure. Well-B – Anisotropic Stress profile for 12.25" section from Advanced acoustic measurement analysis

Dipole sonic anisotropy analysis has been conducted considering vertical well to estimate maximum horizontal stress direction based on applicable fast shear azimuth at depth intervals with stress induced anisotropy. Fast Shear azimuth shows SHMAX direction to be 160 deg. A 70 deg secondary trend is also seen in Fast Shear Azimuth. Both are compliant with the regional inline and crossline faults. Similar trends can be seen in breakouts azimuth also. Refer above figure. NNW-SSE Striking Trends appears to be due fractures / structural deformations compliant with the regional faults. NNW Dipping features appear to be due to structural dip.



Well-B Maximum horizontal stress Azimuth using Advanced acoustic measurements Fast Shear azimuth

Figure:8



Well-B structural features

Figure:9

WELL-B PORE PRESSURE;

Pore pressure is a key component of the MEM, and critical to the calculation of horizontal stresses, wellbore stability analysis and other Geomechanics applications. Apart from direct measurements from well test/MDT tests, pore pressure can be estimated in shaly intervals using several log-based methods (Eaton's, Bower's and Miller's), each typically relating velocity or/and resistivity to the pressure signal in the formation due to under-compaction.

Below figure is a cross plot between compressional slowness and density which is called a Hoesni's plot. It differentiates between different mechanisms of overpressure generation. Based on the theory that compaction increases the grain-to-grain contact of rock matter leading to progressive increase in the density and velocity in these intervals. Under compaction follows the normal (virgin) curve while any significant deviation from the normal trend reflects either a change in the shale composition or a different overpressure mechanism such as an episode of unloading. Regional understanding of pore pressure mechanism is described in Fig. 10. Based on regional experience R and Older Formations exhibit Type-2 overpressure trends. Similar trend can be seen in density-compressional slowness cross plot for R- Formation in the well-B (Fig. 10). The pore pressure profile of well- B was calibrated using well flow events observed while drilling and SBHP measurements available in offset well.

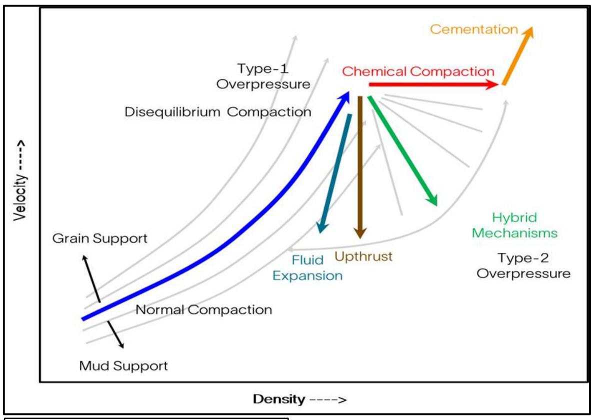


Figure:10

Hoseni's plot showing the overall trend of overpressure

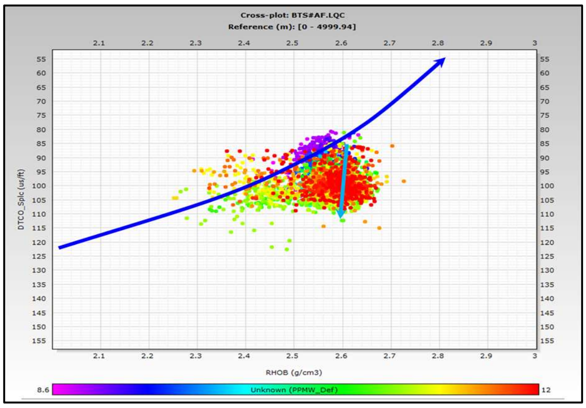


Figure:11

Type-2 Overpressure Mechanism in R- Formation in well B

WELLBORE STABILITY ANALYSIS FOR WELL B (12.25" SECTION);

The best way to calibrate a 1-D MEM is to verify the predictability of the model. Using the computed rock properties and horizontal stresses, wellbore stability analysis tells us how good the MEM is by comparing the predicted wellbore stability with the drilling events observations, breakout or tensile induced fractures observed on caliper or image logs. With the help of advanced acoustic measurements shear velocity radial profiling complicated wellbore failure mechanism can be inferred, if multi arm caliper data or image logs are not available, please refer below Figure.

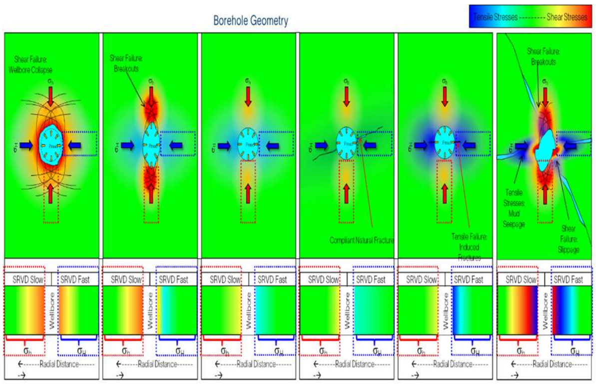


Figure:12

Advanced acoustic measurements shear velocity radial profiling interpretation guide

Below Figure illustrates the wellbore stability analysis for 12.25" section of well B.

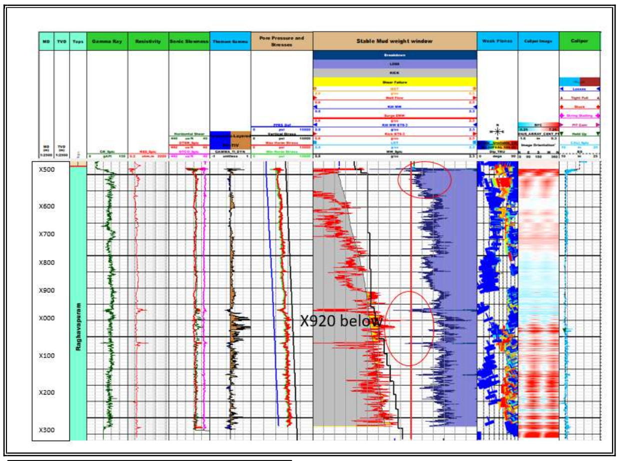


Figure:13

Well B - Wellbore Stability Analysis for 12.25" section

Advanced acoustic measurements 3D Anisotropy analysis is used to determine structural features like dipping beds, faults, fractures etc. near the wellbore that can create local stress tensor rotations from the regional trend. By integrating the 3D Anisotropy analysis and the estimated stress regime, compliance and stability of the structural features is determined to understand their implications on wellbore failure mechanisms and drilling complications.

CBL log was recorded in 13.375-in cased hole section & analysis presented in the below figure;

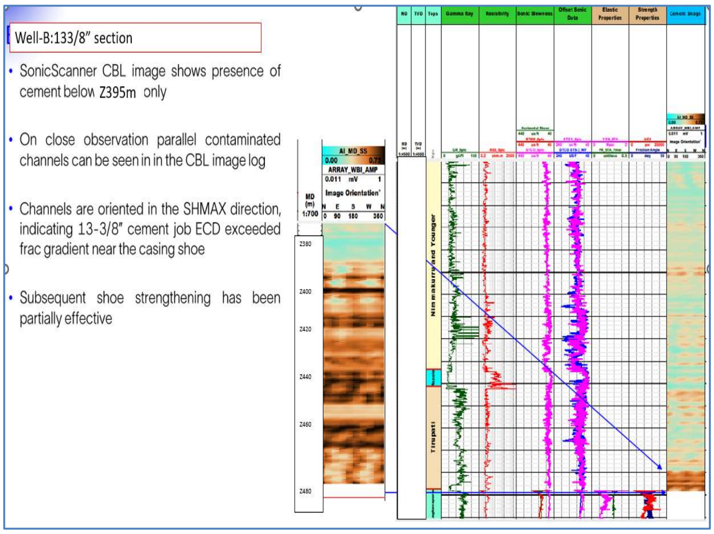


Figure:14

POST-DRILL MEM ANALYSIS FOR 12.25" SECTION OF WELL B

Daily drilling reports were analysed for identifying key events like stuck pipe, held up, losses along with mud weight used till 12.25" section as shown below:

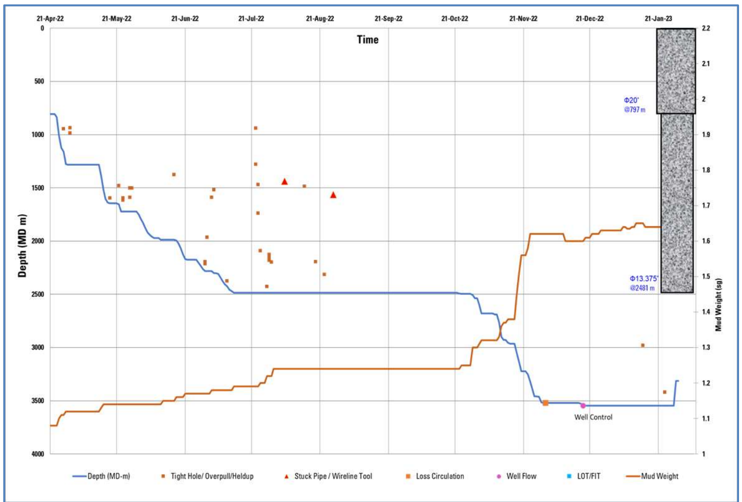


Figure:15

Well-B: Time-depth plot for well B at the end of 12.25" Section

In 12.25” section, static and dynamic mud losses were reported while drilling at X520 m, losses were treated using LCM pill. While drilling at X545 m with MW of 1.6 sg, well flow was observed. Recorded SIDP was 90 psi while SICP 0 psi. MW was increased to 1.61 sg. The well was initially found to be stable with 1.62 sg MW. Later well was found trickling at 35 sec/liter, MW was increased to 1.63 sg. Dynamic mud losses were observed with 1.63 sg MW at X545 m and well was found in loss-gain situation. LCM was used to heal the losses and well was finally found stable at 1.64 sg MW. It was decided to perform intermediate logging in 12.25-in section to assess the loss zones and its further implication on drilling and completion. ***Later the loss zones were isolated using cement plug job and casing shoe was strengthened.***

Significant hole failure is seen below X920m. Cavings/ cuttings are anticipated to have loaded the drilling mud and subsequently leading to ECD surges downhole. Anticipated surge is ~1.7 g/cc downhole for losses to occur at weak zones. ***Three major loss zone are suspected where ECD surge has exceeded the loss gradient. Interval near the casing shoe appears to have critically stressed features/ fractures striking NNW-SSE. Loss/ frac gradient drops below 1.7 g/cc around this interval. This clay does not appear to be weak.***

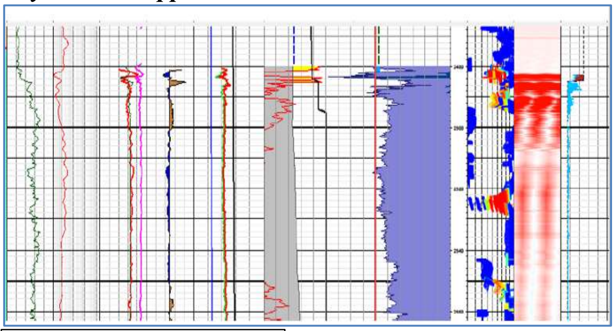


Figure:16

Loss zone (1) near shoe

Two sand layers are seen developed in 12.25” section. Drop in stresses in the sand layers are attributed to presence of critically stressed features in a brittle and permeable lithology. Presence of other critically stressed feature and alternating high-low stress layers are responsible for complex wellbore failure. Cuttings are anticipated to have loaded the drilling mud and subsequently leading to ECD surges downhole.

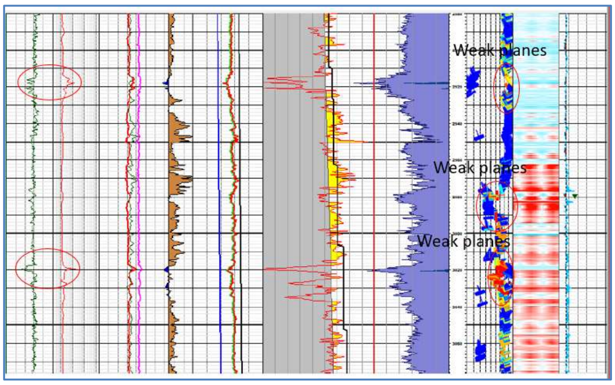


Figure:17

Well-B: Well bore stability: Loss Zone (2)&(3)

SUMMARY OF OBSERVATIONS BASED ON GEOMECHANICAL ANALYSIS FOR THE 12.25” OPEN HOLE SECTION OF WELL-B:

- Overburden stress gradient in wells is ~1.01 psi/ft to 1.06 psi/ft.
- Static and dynamic Losses were observed while drilling 12.25” hole at X520 m. The losses were treated using LCM pills.
- While drilling at X545 m with MW of 1.6 sg, well flow was observed. Recorded SIDP was 90 psi while SICP 0 psi. MW was increased to 1.61 sg. The well was initially found to be stable with 1.62 sg MW. Later well was found trickling at 35 sec/liter, MW was increased to 1.63 sg.
- Dynamic mud losses were observed with 1.63 sg MW at X545 m and well was found in loss-gain situation. LCM was used to heal the losses and well was finally found stable at 1.64 sg MW.
- It was decided to perform intermediate logging in 12.25-in section to assess the loss zones and its further implication on drilling and completion.
- Later the loss zones were isolated using cement plug job and casing shoe was strengthened.
- Several tight pulls/ held up were also observed while drilling 12.25” section.
- As per stress analysis using Sonic Scanner data the maximum horizontal stress direction is 160 deg from North, however a 70 deg secondary trend is also seen in fast shear azimuth analysis.
- Significant hole failure is seen below X920m.
- Cavings/ cuttings are anticipated to have loaded the drilling mud and subsequently leading to ECD surges downhole
- Anticipated surge limit based on 1D MEM is ~1.7 g/cc
- Interval near casing shoe appears to have critically stressed features/ fractures striking NNW-SSE.

- Three major loss zone are suspected where ECD surge has exceeded the loss gradient resulting in subsequent losses observed in well.
- The sand layer developed in R-Formation appear to be major loss zones due to drop in stresses.
- Drop in stresses is attributed to presence of critically stressed features in a brittle and permeable lithology.
- Presence of other critically stressed feature and alternating high-low stress layers are responsible for complex wellbore failure

RECOMMENDATIONS FOR WELL DRILLING BASED ON GEOMECHANICAL ANALYSIS FOR THE 12.25" SECTION OF WELL-B:

Below recommendations were recommended for safe and stable drilling for the remaining 12.25" section:

- Proactive ECD management
- Use Stable Mud Weight Windows from Anisotropic Geomechanical studies.
- Proper hole cleaning procedures to be followed for ECD management
- Use of wellbore strengthening material/fluid loss additives
- This will prevent shear-slip failure
- Cure losses in permeable sands
- Proactive use of a blend of particulate and fiber material is recommended during drilling
- 13-3/8" casing cement repair is also strongly recommended
- Cementing ECD should be below 1.7 g/cc
- Block squeeze/ circulation squeeze techniques may be looked into
- Equivalent Static Density (ESD) should be maintained above maximum collapse pressure whenever circulation is not feasible (tripping/casing running/ logging/ connection). While POOH drilling BHA, it is advised to pump out of hole to minimize damages across weak zones due to swab effect. Special care needs to be taken to avoid swabbing while tripping out of hole.
- Place viscous & heavy pills to maintain ESD above max collapse pressure
- Under-reamers may be considered to prevent ECD surges
- Due to numerous stress rotation and weak planes, use of wellbore strengthening material/ fluid loss additive is strongly advised along with proactive ECD management to prevent weak plane related failure and other subsequent drilling complications.
- If losses are observed while drilling, LCM should be used to cure the losses.

LOOK AHEAD PPFG MODEL FOR WELL-B:

Look ahead PPFG model was created for remaining 12.25" section till X900m and for till X782 m for 8.5" section. Below is the key takeaways:

FOR 12.25" SECTION TILL X900 M:

- Overburden Gradient is ~2.39gm/cc
- Maximum expected Pore pressure is ~1.63 g/cc
- Expected Fracture Gradient is in the range from ~1.76 to ~2.15 gm/cc
- Some permeable sands might have relatively lower fracture gradient ~1.7 gm/cc
- ECD needs to be maintained below ~1.7 gm/cc to prevent mud losses
- To prevent borehole collapse ESD needs to be maintained above ~1.65 g/cc in static condition (logging/ Tripping/casing)
- 12.25" Section can be drilled till X900 m provided ECD and hole collapse limits are honored.

FOR 8.5" SECTION:

- Overburden Gradient is ~2.46gm/cc
- Based on available formation pressure and drilling events in offset wells, two cases of lookahead PPFG profile was created to capture the uncertainty.
- Maximum expected Pore pressure is ~1.96 g/cc for high case (Type-2 over pressure mechanism)
- From ~4000 m another Type-2 pore pressure ramp is expected
- Expected Fracture Gradient ~2.15-2.24 gm/cc (Low Case)
- ECD needs to be maintained below ~2.15 gm/cc to prevent mud losses

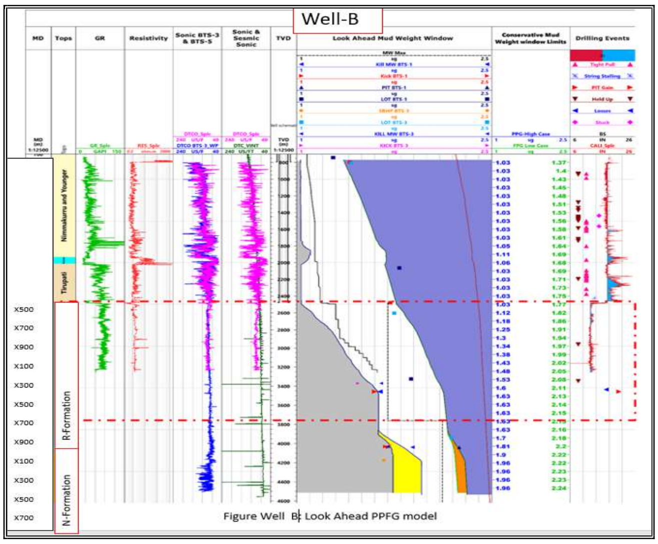


Figure:18

Successful drilling & completion of the Well-B
Based on Geomechanical results:

- ➔ Loss zones were isolated using cement plug job and casing shoe was strengthened.
- ➔ LCM pills were used to cure the losses.
- ➔ Further 12.25-in section was drilled honoring mud weight window obtained using Geomechanical analysis and successfully carried out 9.625-in casing running and cementation job.
- ➔ 8.5-in section was drilled successfully upto X400m with look ahead mud weight window and recommendations.

Conclusions & recommendations:

By using the invaluable insights from Geomechanical analysis for drilling operations, loss zones identification, and using safe mud weight window, the well was drilled and casing was cemented in place successfully. Using anisotropic properties for a wide range of rock fabric provided a better understanding of the downhole stress state. Mud-loss gradient using an anisotropic model approach for the R-Formation section helped to identify medium- to high-risk mud-loss-prone layers, which enabled us to change tripping speed and optimize the use of chemicals to seal such layers. The recommended mud weight based on constrained horizontal stresses using advanced acoustic data helped us to optimize mud weight in the remaining 12.25-in section & 8.5-in. section. This protected and preserved the hole condition, which helped in correctly perform formation evaluation and obtain good-quality well logs. Advanced shear radial profile based direct horizontal stress profile values reduces uncertainty in the anisotropic poro elastic horizontal strain method based horizontal stress determination. The recommended mud weight should is in the range of 1.96-2.24 g/cm3 at the start of the N- Formation in this well-B and should be proactively increased to manage borehole breakouts.

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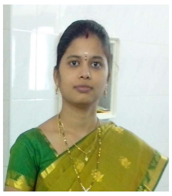

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