# Geomechanical Evaluation in Shale for selected wells of North Cambay basin: A case study

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**Summary**

Geomechanics plays a critical role in successfully optimizing shale exploration and exploitation. The geomechanical study of a shale reservoir essentially requires the measurement of rock mechanical properties, strength parameters along with the state of in situ stress in order to better identify the intervals which can be effectively fractured. Two exclusive shale wells in North Cambay Basin were studied and 1D Mechanical Earth Model (MEM) for each well comprising of overburden, pore pressure, fracture pressure, rock compressive strength, rock elastic properties, horizontal stresses and wellbore stability plots for drilling horizontal wells have been prepared and caliberated with available geological, rock mechanical and drilling data.

## Introduction

Geomechanics plays a pivotal role in well placement and well completion jobs. Shale wells are often drilled horizontal or high-angled to maximize the reservoir exposure. Given the fact that drilling a normal vertical well itself is difficult in a shale section, it is going to be very problematic to drill a horizontal well unless we have a robust mechanical earth model in place. Additionally, with the knowledge of stress orientation we can optimize both the well placement and the hydraulic fracturing job.

The two studied vertical wells are from different fields of North Cambay basin, which falls in Ahmedabad-Mehsana block (Figure 1). The formations considered for this study are Younger Cambay Shale, Older Cambay Shale and Olpad formations of Paleocene-Eocene age.

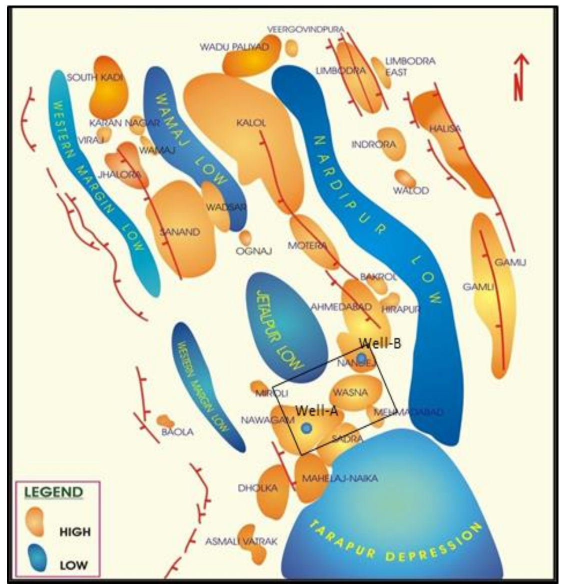


Figure 1: Map of the study area with well distribution

## Methodology

To prepare a 1D Mechanical Earth Model, different rock mechanical properties are needed as an input viz. Unconfined Compressive Strength, Young's Modulus, Poisson's Ratio, Tensile Strength, Coefficient of internal friction etc. this MEM assist in understanding the geomechanical conditions around the wellbore to predict wellbore failure and determine optimal drilling trajectories and mud weights. In addition, the orientation of productive fractures can be determined.

## Overburden/ Vertical Stress Estimation:

Overburden stress ($\sigma v$) is the pressure exerted on a formation at a given depth (z) due to the total weight of the rocks and fluids above that depth (McGarr and Gay, 1978) and calculated by using the following equation,

$$S_v = \sum_{0}^{z} g\rho(z)dz$$

Where ρ(z) is the bulk density at depth z, g is acceleration due to gravity.

**Pore Pressure Estimation:**

In this study Eaton's trend line method has been used for computing pore pressure from sonic data (Figure 2).

$$P = S - (S - P_{hyd}) \left(\frac{\Delta t_n}{\Delta t_{log}}\right)^n$$

Where P and S are pore pressure and overburden stress, $P_{hyd}$ is hydrostatic pressure $\Delta t_n$ and $\Delta t_{log}$ are normal and real transit time of sonic wave in the formation respectively and n is fitting parameters named Eaton exponent.

The values used for Eaton's method using compressional slowness is: n=3.

However, no direct measurements from well test/MDT tests is available in these wells.

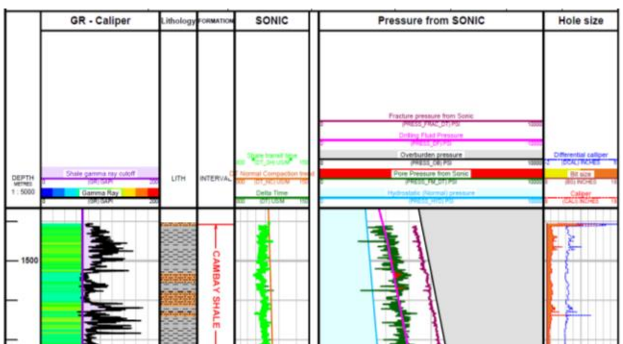


Figure 2: Pore pressure estimation in well-A

Hoseni curve (density-velocity cross plot) differentiates between different mechanisms of overpressure generation. It was prepared for Cambay Shale & Olpad section for both wells and Normal/disequilibrium compaction was found out the most common mechanism encountered in these wells (Figure 3).

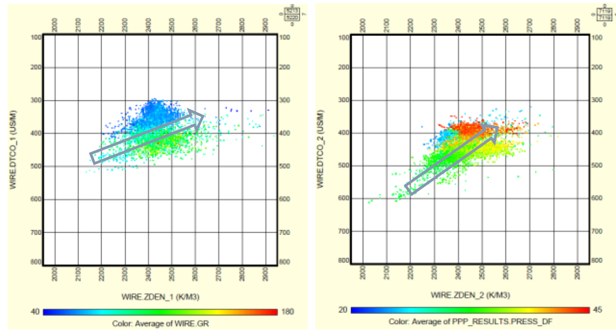


Figure 3: Hoseni plots for well A & B

**Rock Elastic Properties & Rock strength:**

In this study two elastic properties (Young's modulus and Poisson's ratio) are selected to derive the static values of Static Young's modulus and Static Poisson's Ratio from log. These values are showing good match with values estimated through triaxial rock test carried out in well A (Figure 4).

**$lnE_{static}$= 14.9-0.61*ln(DTCO)-2.18*ln(DTSM)+ 1.42*ln (RHOB)**

**$PR_{sta} = 0.8*PR_{dyn}$** **$T_{STR}$= 0.1 * UCS**

$$UCS = 0.77*\left(\frac{304.8}{DTCO}\right)^{2.93}$$

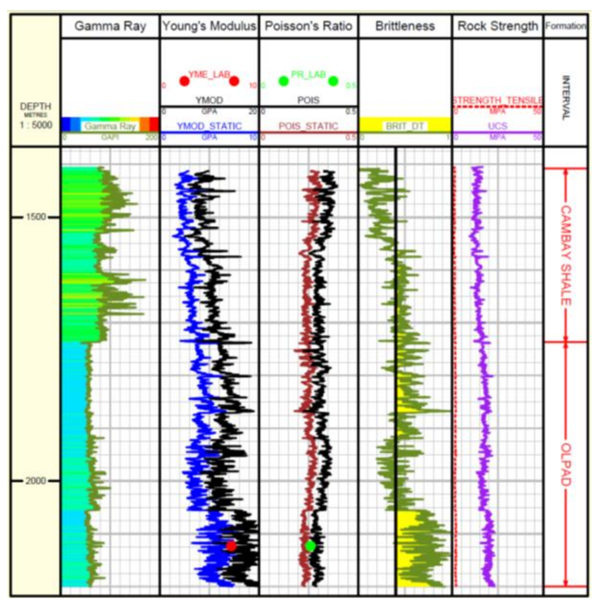


Figure 4: Computed Elastic properties and Rock strength for well-A.

**Stress magnitude determination:**

In this study, a poro-elastic horizontal strain model (Thiercelin, M.J., and Plumb, R.A. 1994) is used to estimate the magnitudes of the minimum and maximum horizontal stresses (Figure 5) based on anisotropic poroelastic horizontal strain model.

$$S_{hmin} = \frac{PR}{1-PR}(S_V - \alpha PP) + \alpha PP + \frac{YMS}{1-PR^2}\epsilon_{Hmax} + \frac{YMS \times PR}{1-PR^2}\epsilon_{Hmin}$$

$$S_{Hmax} = \frac{PR}{1-PR}(S_V - \alpha PP) + \alpha PP + \frac{YMS}{1-PR^2}\epsilon_{hmin} + \frac{YMS \times PR}{1-PR^2}\epsilon_{Hmax}$$

Where PR is Poisson's ratio, $S_V$ is vertical stress, α is Biot's coefficient, PP is pore pressure, YM is the static Young's Modulus, $\epsilon_{Hmin}$ and $\epsilon_{Hmax}$ are the minimum and maximum horizontal strain.

The magnitude of minimum horizontal stress caliberated with minifrac and LOT data while borehole breakout observations from image logs was used to validate the SHmax.

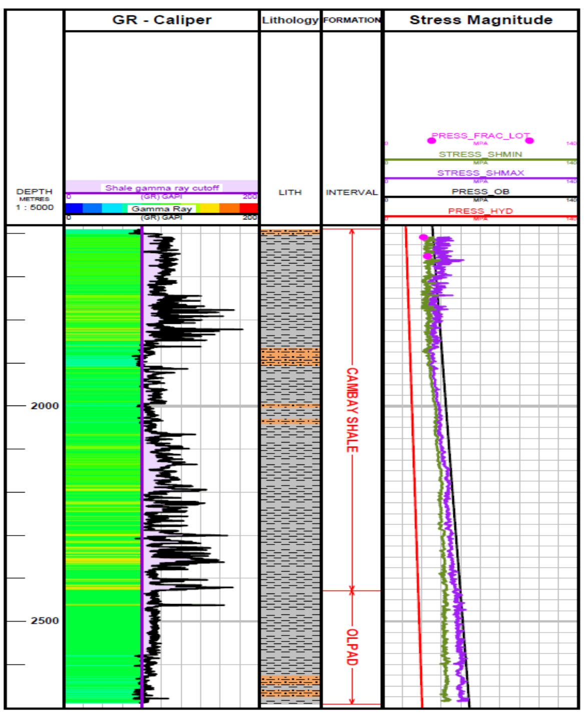


Figure 5: Magnitude of Horizontal stress in well-B

**Direction of Horizontal Stresses:**

The direction of SHmin and SHmax was determined by borehole breakouts and drilling induced tensile fractures (DITF) respectively, as both these phenomenon can be very well seen on an image log (Figure 6).

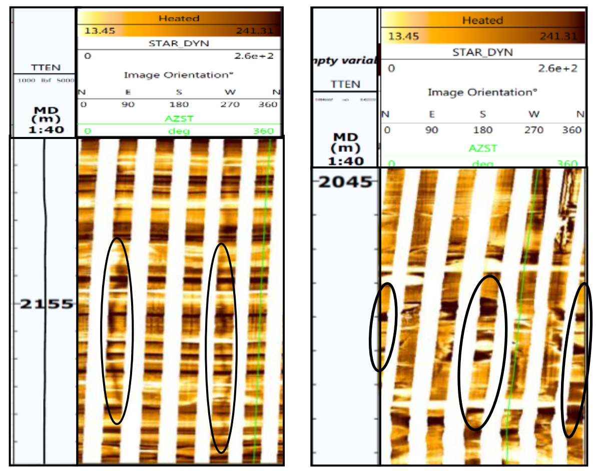


Figure 6: Direction of horizontal stresses in well A and B.

The DITF direction in Well A is 50/230° which is the SHmax direction. In the same figure (right image) shows breakouts oriented in 160/340° which is the azimuth for SHmin in Well B. As the principal stresses are orthogonal to each other, the azimuth of SHmax in Well B is 70/250°.

**Conclusions**

- The Cambay Shale interval in well A is in Normal fault regime, while the Olpad falls in Normal to strike-slip regime. Similarly in well B, Cambay Shale lies in Normal to strike slip and Olpad is in Normal fault setting.

- Shales are observed to be over-pressured, primarily because of compaction disequilibrium, which is evident from Density-Velocity plots (Hoseni curves).

- The estimated Static YME and Static PR through different correlations were matched with lab data at these points and they were seen to be in agreement. Based on these computed values the Cambay Shale intervals are mostly ductile in nature.

• The Maximum Horizontal Stress direction for the area is NE-SW (Figure 7).

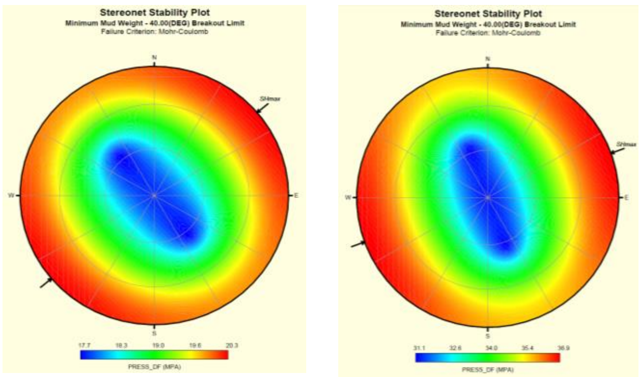


Figure 7: Wellbore stability plot for a given depth in well-A and B.

The optimum direction for drilling horizontal wells in the area for effective hydraulic fracturing and maximum production would be NW-SE.

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