Wellbore Stability Analysis and Pore Pressure Study in Badri Field Using Limited Data, Gulf of Suez, Egypt*

Ahmed E. Radwan[1,2]

[1]Exploration Department, Gulf of Suez Petroleum Company, Cairo, Egypt (radwanae@yahoo.com)
[2]Faculty of Geography and Geology, Institute of Geological Sciences, Jagiellonian University, Gronostajowa 3a, 30-387, Kraków, Poland

Abstract

Wellbore stability analysis and stresses definition is highly recommended, especially in deviated wells, which impacts drilling costs. The limited amount of data is a challenge in this study.

The objectives of this study are firstly to build a geomechanical model for the Badri Field region using data from four offset wells, along with structural information and regional experience, secondly to utilize a geomechanical model and perform a wellbore stability analysis for the next development well, and thirdly to provide a quantitative risk analysis (QRA) to understand the uncertainty in model parameters and assess the effect on mud weight recommendation. A geomechanical model was constructed for the Badri Field based on data from four key offset wells; the model includes the overburden gradient, pore pressure, minimum and maximum horizontal stresses, and rock strength. The model was calibrated to drilling experience, which includes geomechanical-related problems.

Based on the field geomechanical model, wellbore stability analysis was applied to the provided trajectory for the next development well. No safe mud window is predicted for the trajectory due to the effect of expected depletion in the Kareem and H. Faraun formations, and on the expected minimum horizontal stress. There is uncertainty in model parameters (i.e. expected depletion could be lower or higher, no rock mechanical data to calibrate collapse pressure or stress path parameters). The initial fracture gradient is a conservative estimate (towards lower bound), thus the fracture gradient could be higher and a mud window could exist. Additionally, there is lack of UCS calibration data and lack of image data for constraining maximum stress magnitude and orientation. Because of these limitations, the standard model verification is more difficult, however a general sense of the drilling experience along with the model derived (which relies heavily on offset well drilling experience) is utilized for predictions for the planned well.

It is recommended to drill with a mud weight of ~10.6 ppg and add appropriate bridging/sealing/LCM materials to increase wellbore strength and reduce the possibility of differential sticking in some intervals. It is also highly recommended to run real time WBS monitoring. Monitor model and drilling parameters in real-time using appropriate LWD and SLS logs, and pay close attention to cavings to diagnose failure

mechanisms, in order to adjust the mud weight as necessary if problems arise. Due to the quality/lack of input data, further data collection is recommended on future wells for refining the model, continue to run logs (acoustic, density), and apply the appropriate gas corrections. Core for lab testing and calibrating mechanical rock properties is highly recommended and image logs for modeling the maximum stress field. It is also recommended to view the model within a holistic approach, doing an in depth look into mud composition/additives effects on stability, as well as drilling parameters effects (comparing things like ROP, hole cleaning efficiency, etc.). Most importantly, with mud window recommendations it is suggested that efficient hole cleaning and drilling practices will result in the well reaching Total Depth with minimal NPT.

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1- The Objective

The main objectives of this study were firstly to build a geomechanical model for the Badri field region using limited available data from four offset wells along with structural information and regional experience, secondly utilizing the geomechanical model and perform a wellbore stability analysis for the next development well, thirdly Provide a quantitative risk analysis (QRA) to understand the uncertainty in model parameters and assess the effect on mud weight recommendation results.
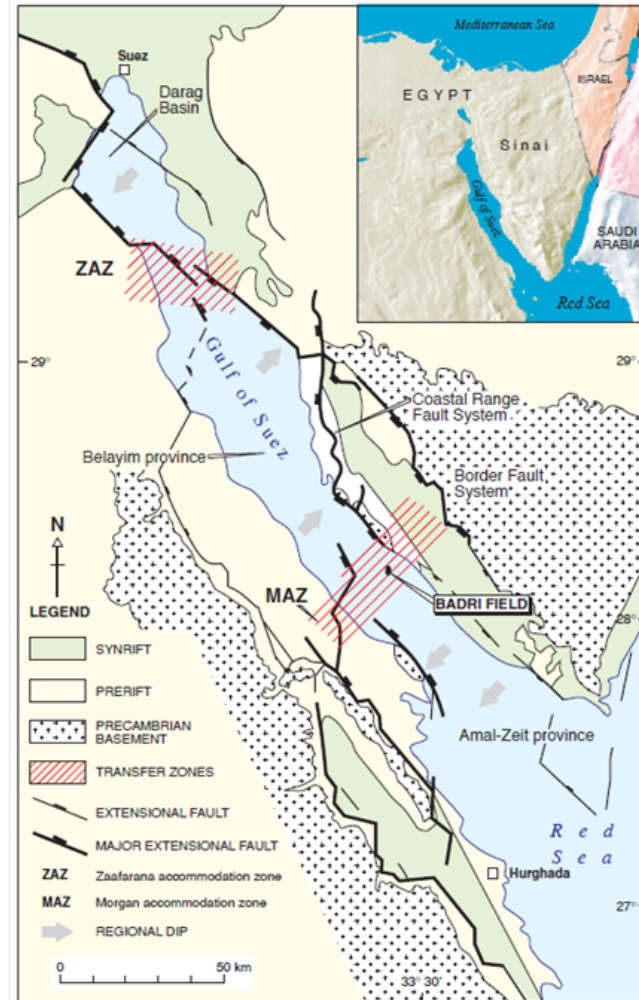
Area of Study

Fig.1; Tectonic element of the Gulf of Suez where the studied field location illustrated (Radwan, 2018 a,b,c,d).
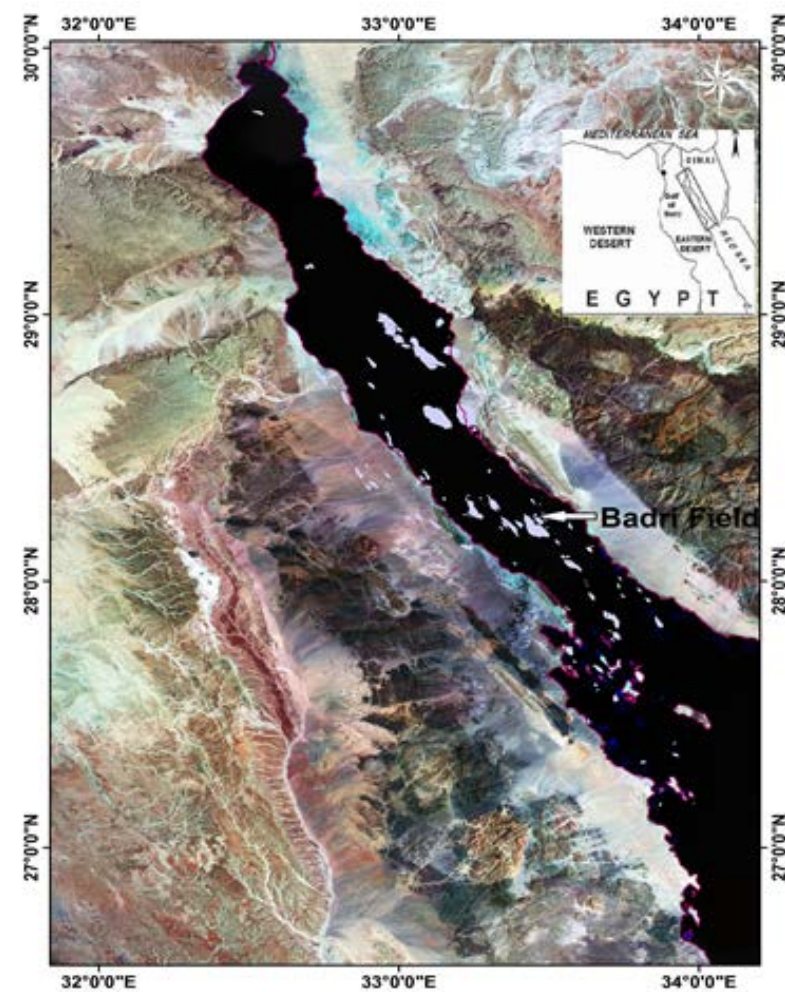
Fig.2; Tectonic element of the Gulf of Suez where the studied field location illustrated (Abudeif et al., 2016a,b; Abudeif et al., 2018; Radwan, 2019a,b,c).
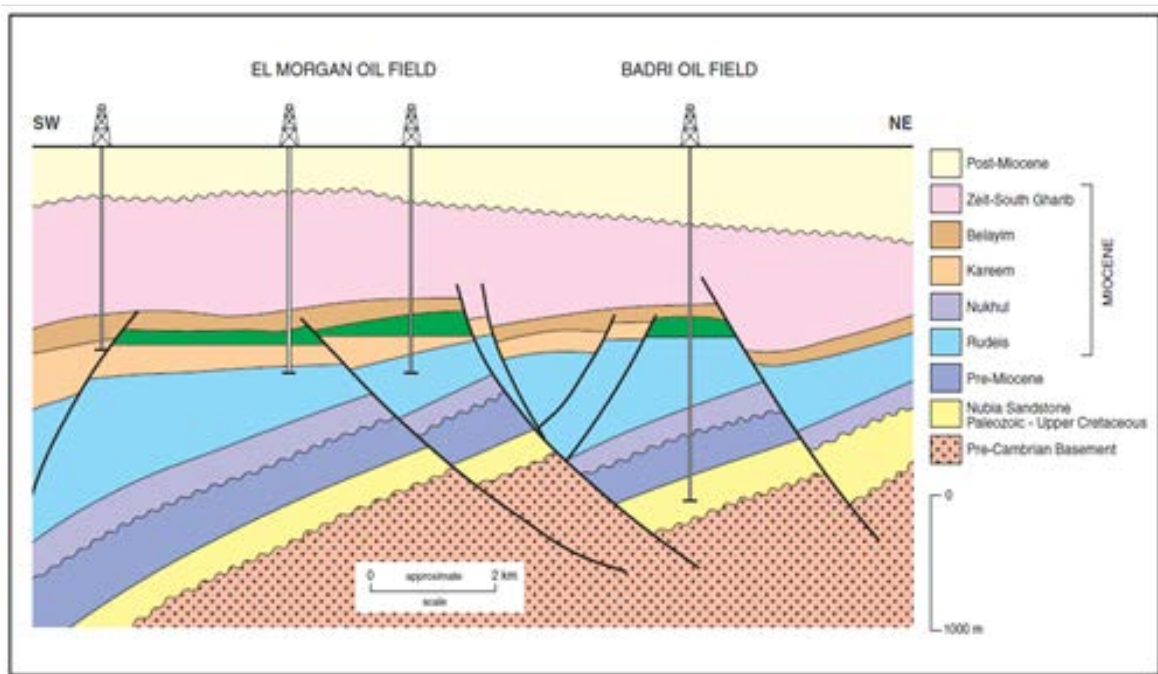
2. Structural settings

Fig.3; Generalized SW-NE cross-section showing the stratigraphy and structural relationship of the El Morgan Field and the nearby Badri Field (Radwan, 2018 a,b,c,d).
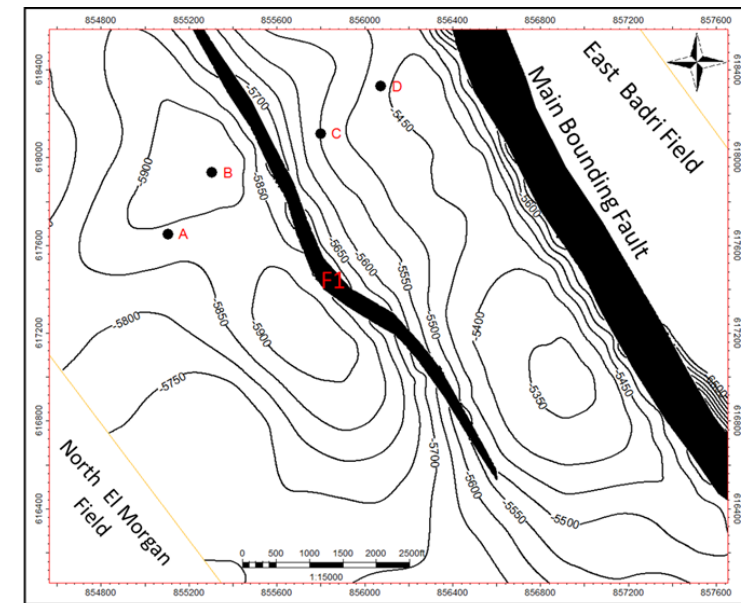

Fig.4; Structure contour map of Baba Member in Badri Field, where the Studied wells location illustrated, countouring represent elevation depth values. (Abudeif et al., 2016a,b; Abudeif et al., 2018; Radwan, 2019a,b,c; Radwan 2020a,b).

3. Lithostratigraphy

Fig.5; the stratigraphy and structural relationship of the El Morgan Field and the nearby Badri Field (Abudeif et al., 2018; Radwan, 2018 a,b,c,d).
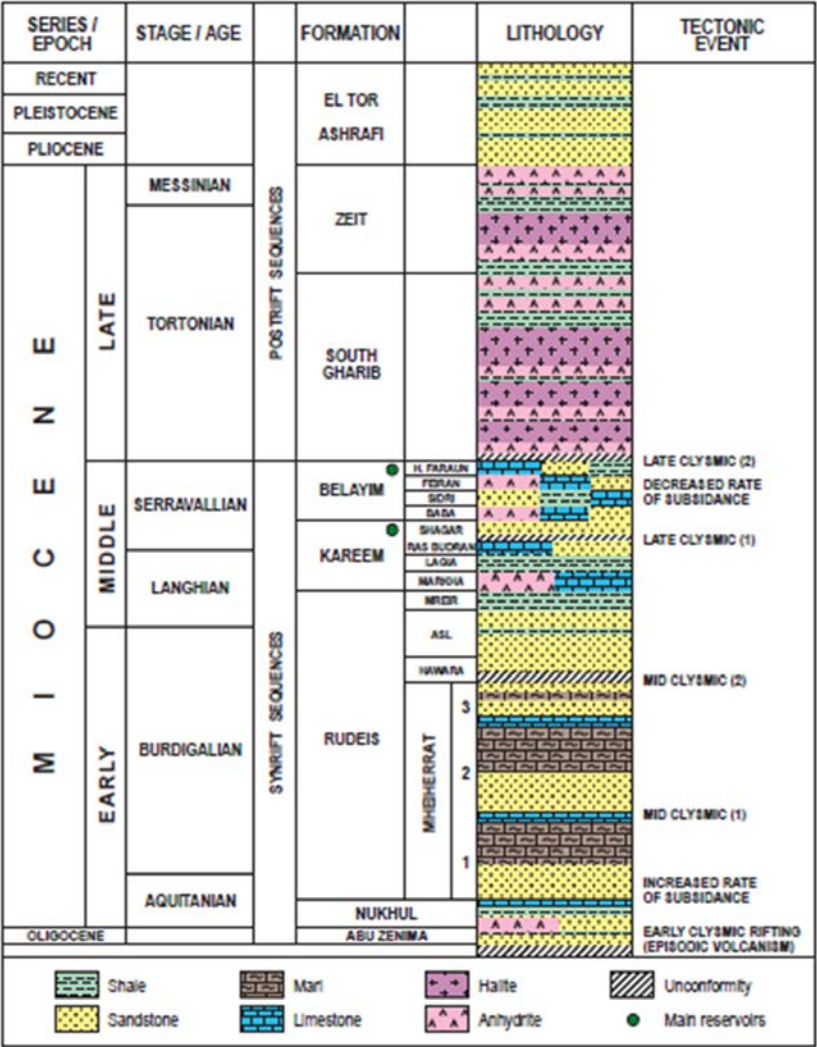
4. Methodology

*Data Availability: Limited Density, Sonic and Resistivity logs were available in the studied area.
*Overburden Gradient…… Amoco Method
*Basin Modelling
*Direct pressure measurements
RFT …………………….in Reservoirs.
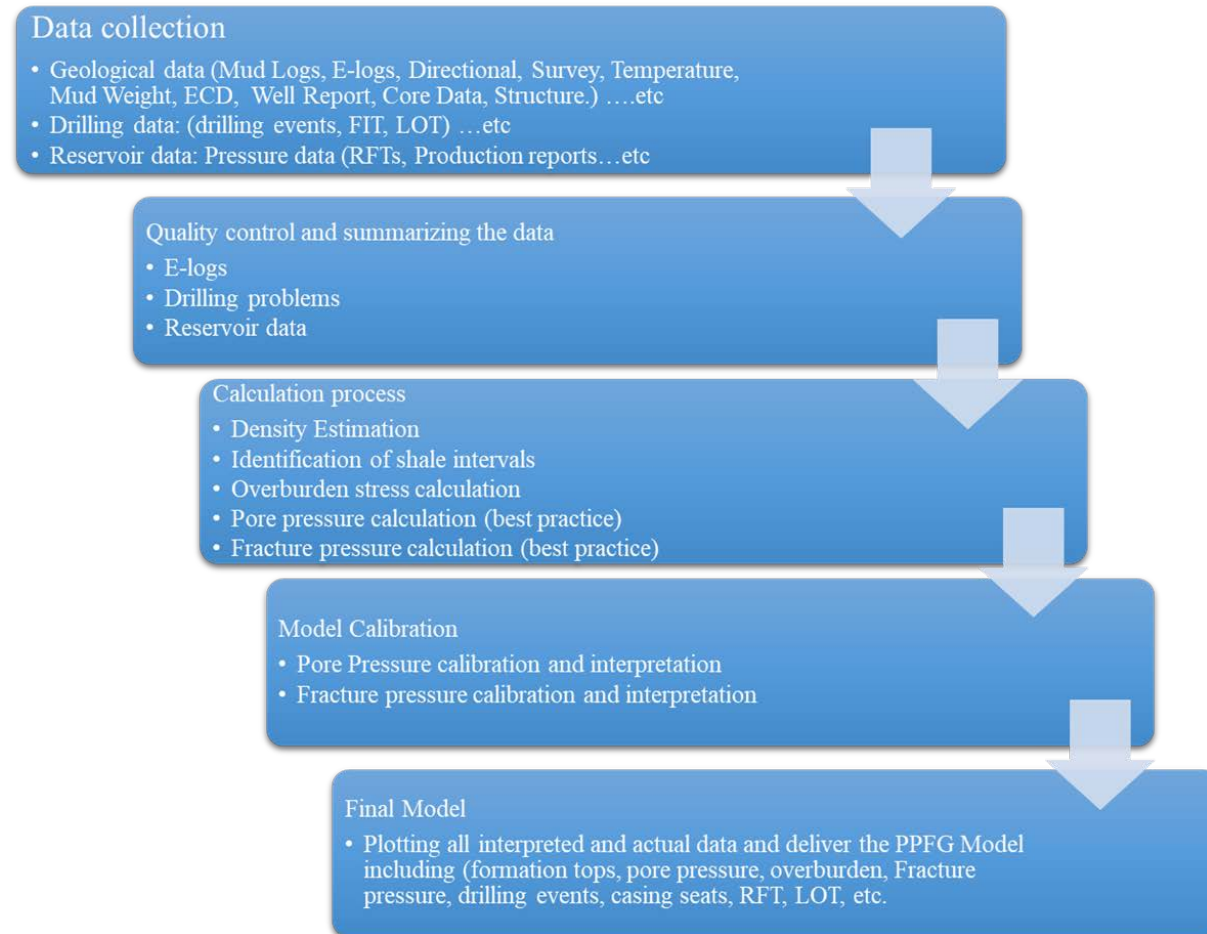*Indirect methods
Eaton's resistivity, and sonic (1972 and 1975)
$PP = OBG - (OBG-PPN) * (\Delta To /\Delta TN)x$
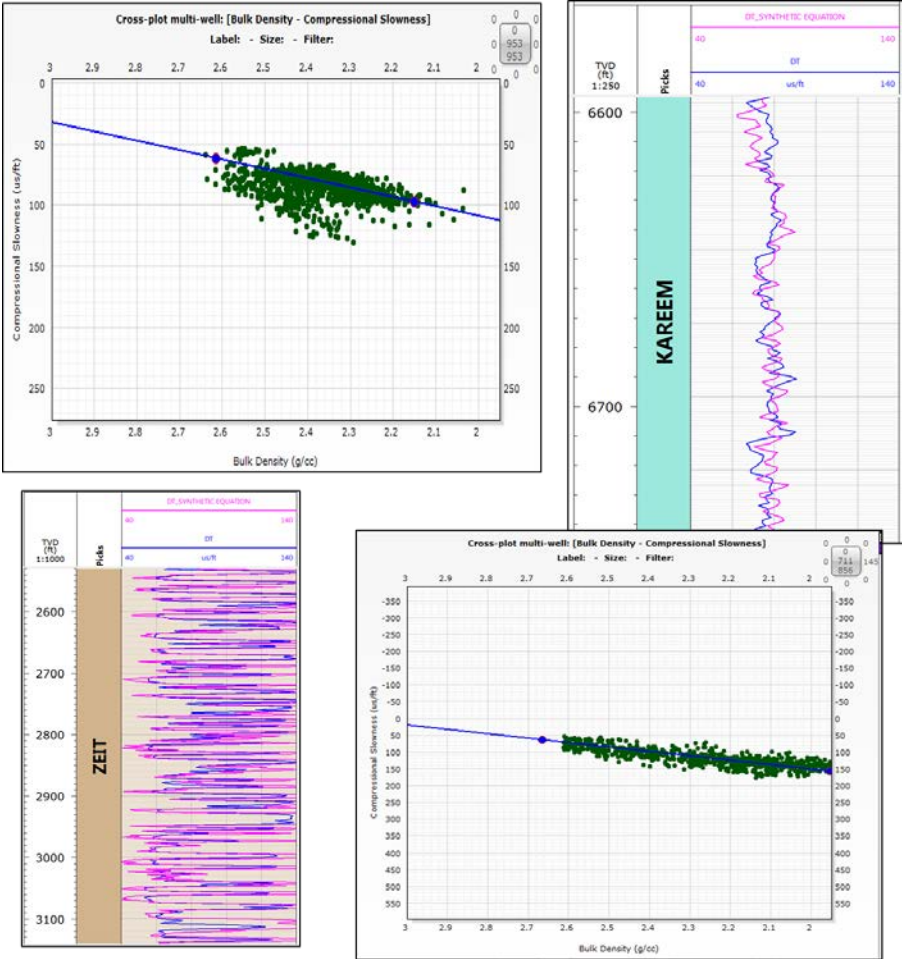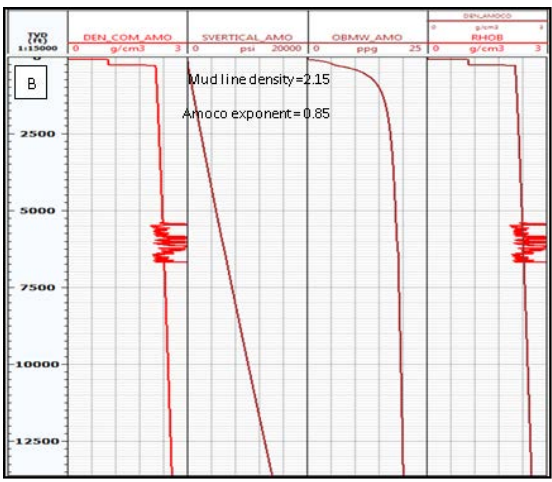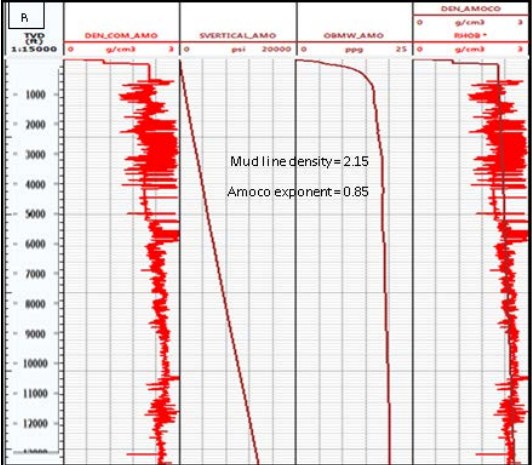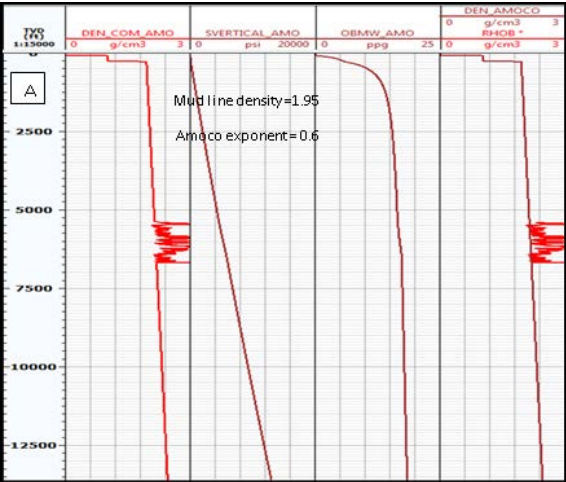$PP = OBG - (OBG - PPN) (Ro/ RN)x$
Eaton's Fracture method, K.
*Drilling Problems
Used to calibrate the pore pressure results

4. Methodology

Data collection
- Geological data (Mud Logs, E-logs, Directional, Survey, Temperature, Mud Weight, ECD, Well Report, Core Data, Structure.) ….etc
- Drilling data: (drilling events, FIT, LOT) …etc
- Reservoir data: Pressure data (RFTs, Production reports…etc

Quality control and summarizing the data
- E-logs
- Drilling problems
- Reservoir data

Calculation process
- Density Estimation
- Identification of shale intervals
- Overburden stress calculation
- Pore pressure calculation (best practice)
- Fracture pressure calculation (best practice)

Model Calibration
- Pore Pressure calibration and interpretation
- Fracture pressure calibration and interpretation

Final Model
- Plotting all interpreted and actual data and deliver the PPFG Model including (formation tops, pore pressure, overburden, Fracture pressure, drilling events, casing seats, RFT, LOT, etc.
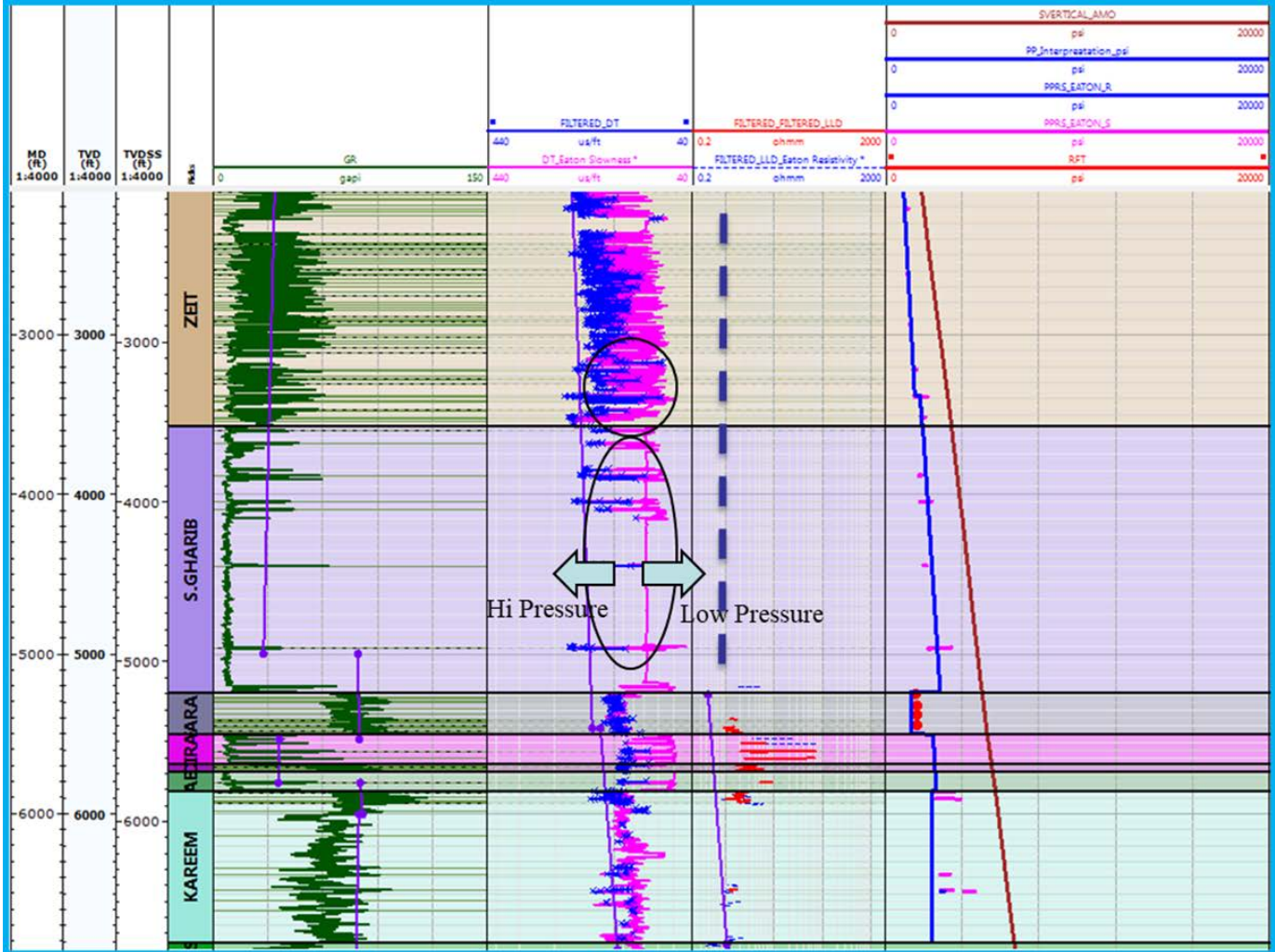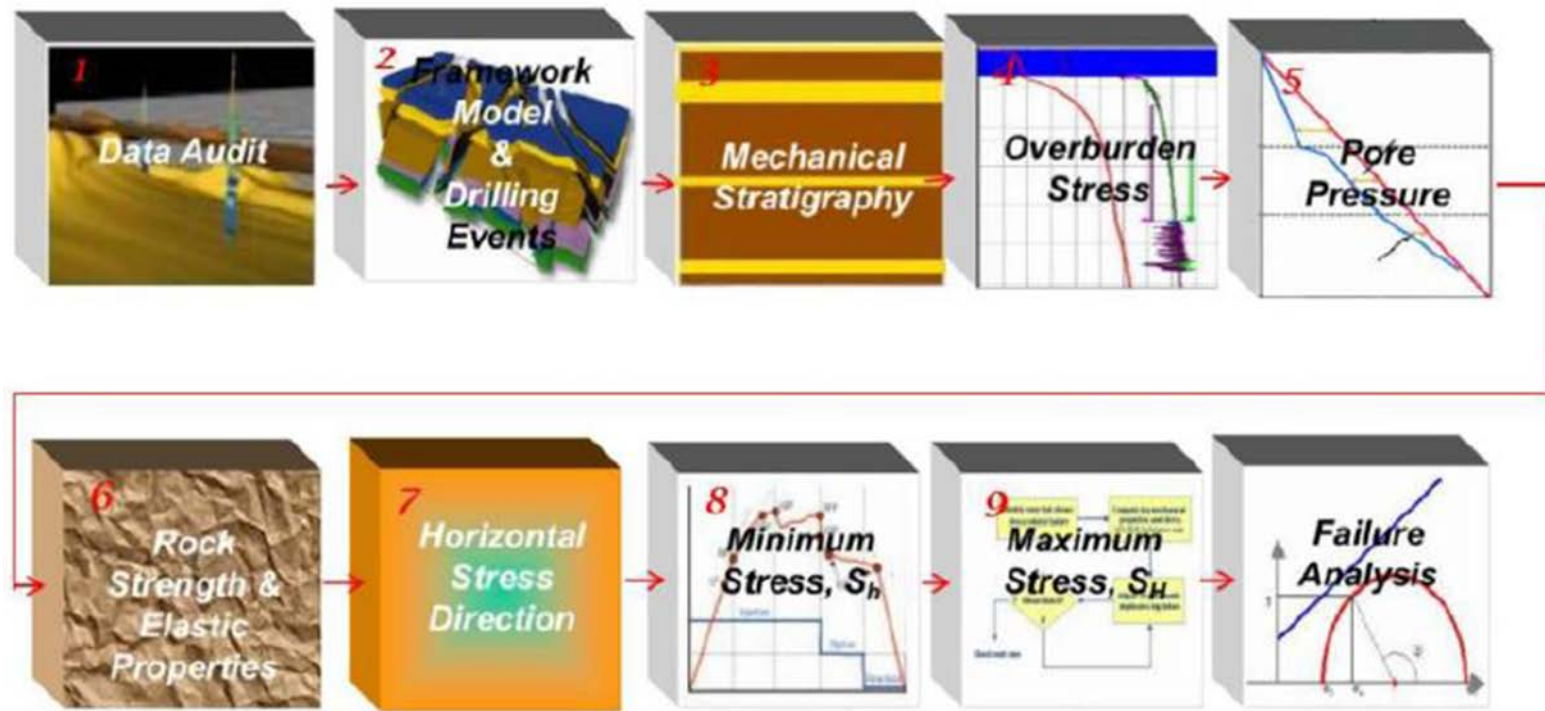
4.1. PPFG model

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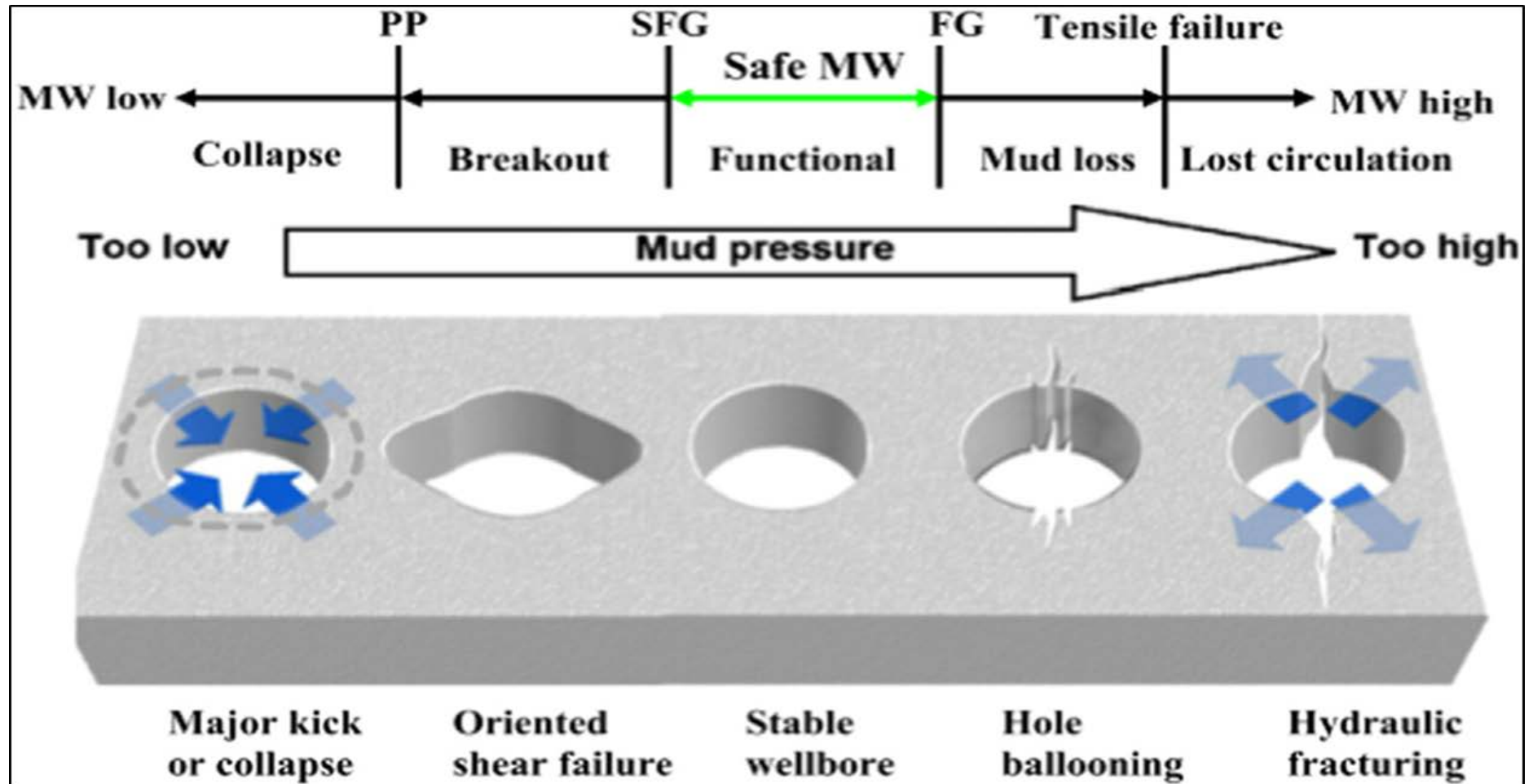**pore pressure prediction using Eaton sonic and resistivity methods**

4.2 Mechanical Earth Model

This module combines stresses direction and magnitude data, MEM and wellbore-stability analysis with a depth-of-damage approach. The depth of damage analysis, predicted the severity of wellbore instability to give drillers a sense of the wellbores likely conditions and behavior. It also provides the model with several mud weight windows as window of possible losses, tunnel failure possible (from 0-5%), manageable failure (5-10%) and high risk curve limit (10-20%).
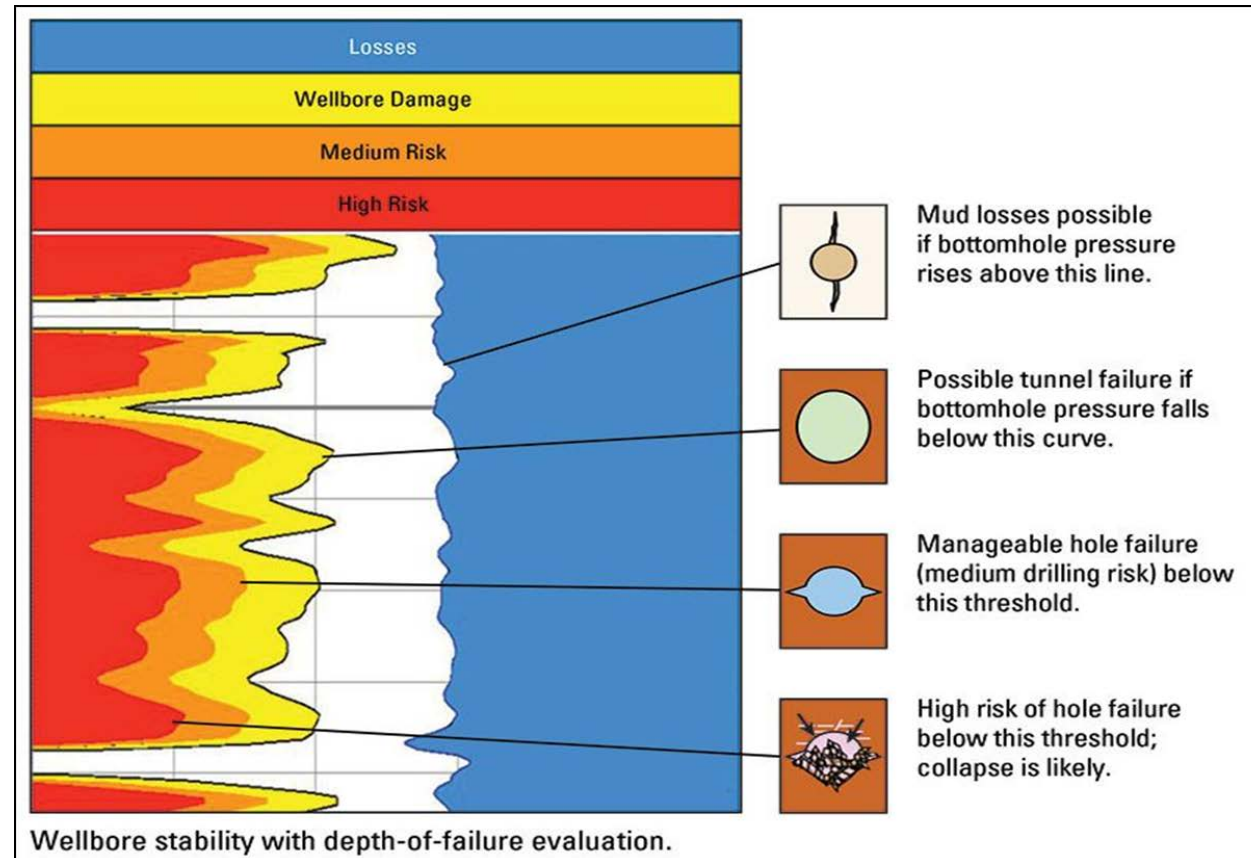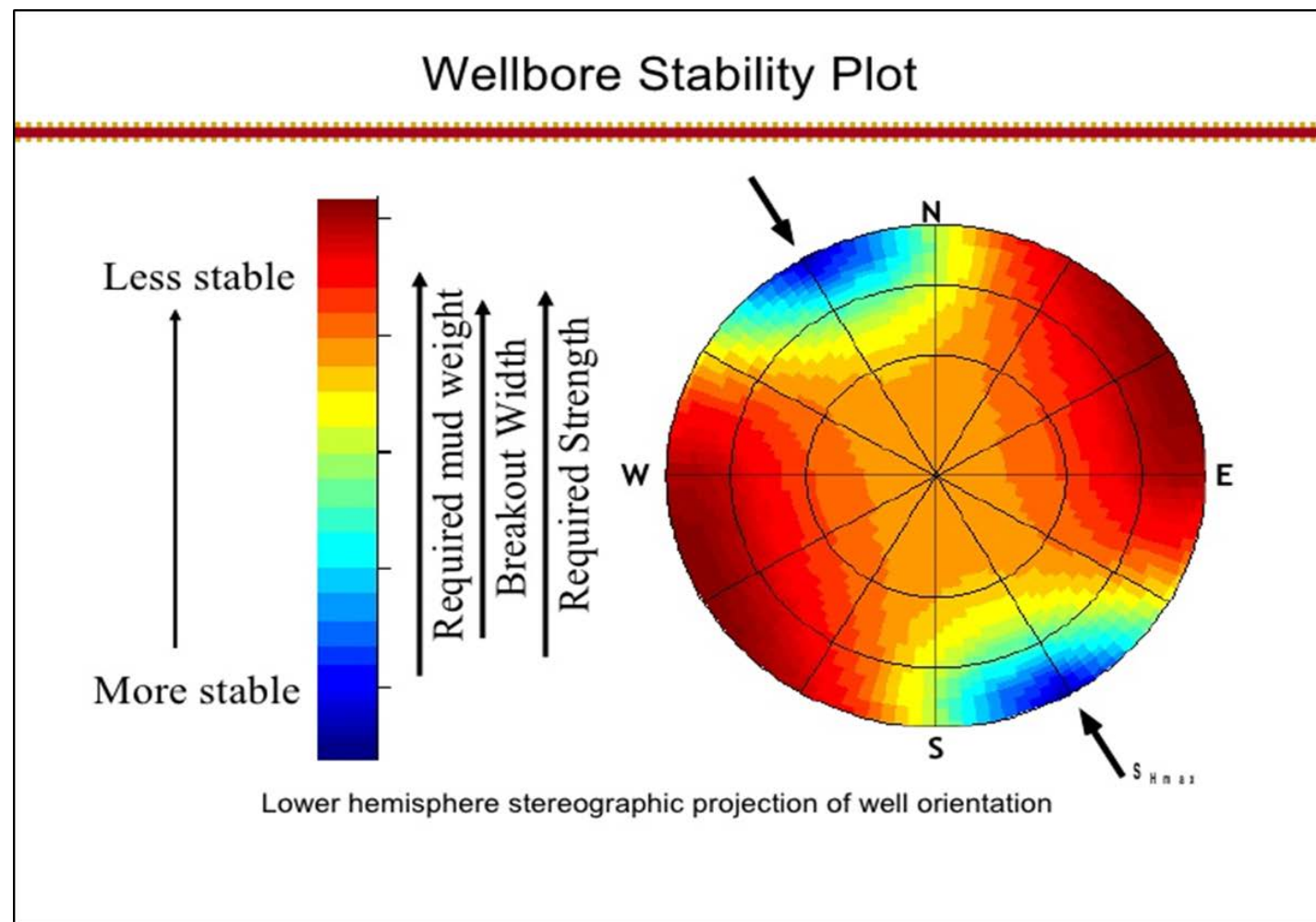
4.2 Mechanical Earth Model
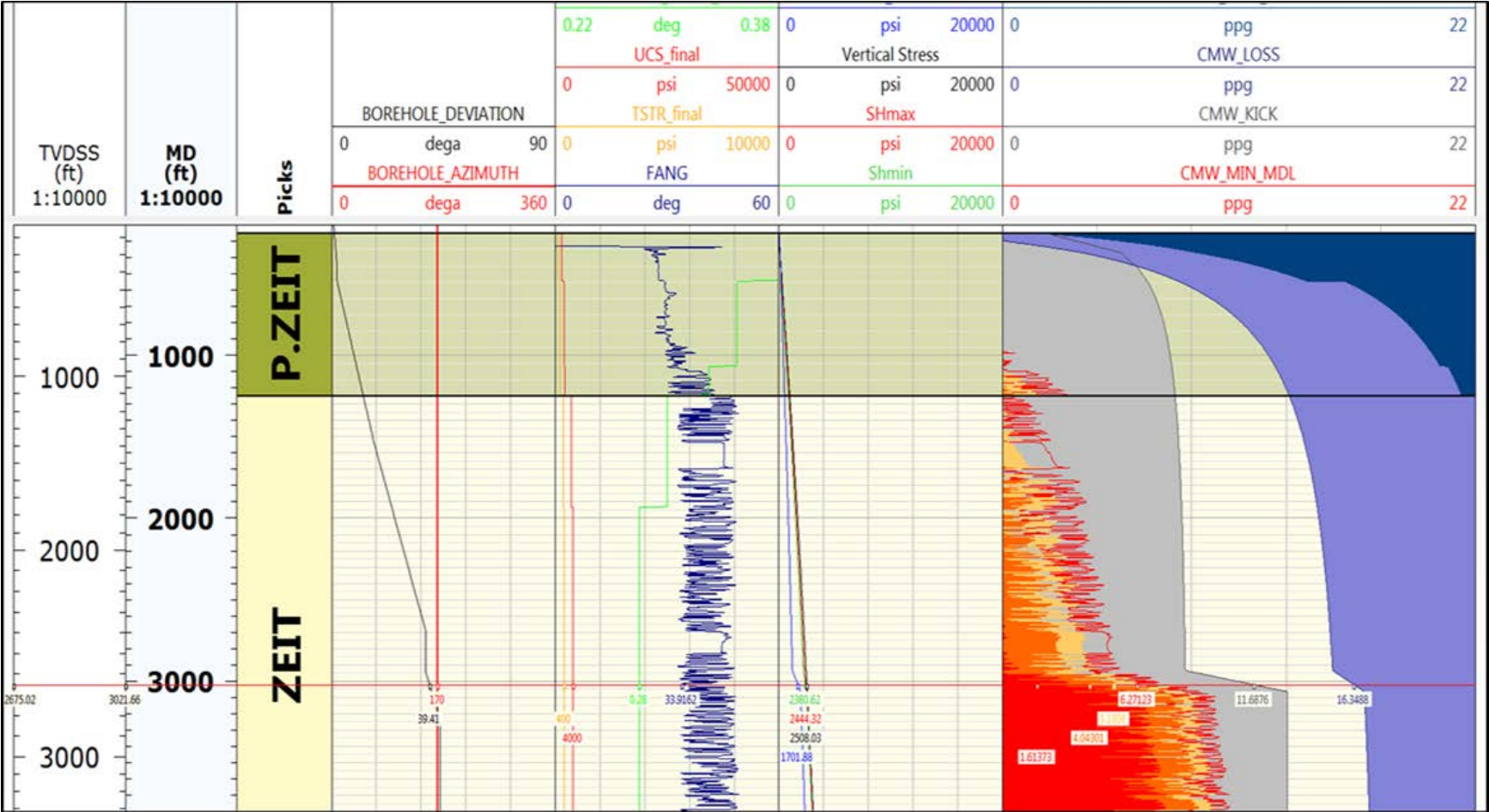
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Wellbore stability with depth-of-failure evaluation.

4.2 **Mechanical Earth Model**

Wellbore Stability Plot

Less stable

More stable

Required mud weight

Breakout Width

Required Strength

N

W

E

S

S_{Hmax}

Lower hemisphere stereographic projection of well orientation

4.2 Mechanical Earth Model

Conclusions

The results of this study revealed that,
1) Low safe mud window is predicted for the well trajectory, due to the effect of expected depletion in the Kareem and H.Faraun formations.
2) There is uncertainty in model parameters (i.e. expected depletion could be lower or higher, no rock mechanical data to calibrate collapse pressure or stress path parameters). The initial fracture gradient is a conservative estimate (towards lower bound of LOTs), thus the fracture gradient could be higher and a mud window could exist.
3) It is recommended to drill with a mud weight of ~10.6ppg and add appropriate bridging/sealing/LCM materials to increase wellbore strength and reduce the possibility of differential sticking in some intervals. It is also highly recommend to run real time WBS monitoring. Monitor model and drilling parameters in real-time using appropriate LWD and SLS logs, and pay close attention to cavings in order to diagnose failure mechanisms, in order to adjust the mud weight as necessary if problems arise.