PS Integrated Geomechanical Approach in Characterizing Sealing Capability of Faults in Cretaceous Carbonate Reservoirs, Abu Dhabi*

Manhal Sirat[1], Ashok Shinde[2], and Satya Perumalla[2]

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[1]ADCO
[2]Baker Hughes (Ashok.Shinde@bakerhughes.com)

Abstract

The main objective of this study is to quantify the subsurface geomechanical conditions that favor the development of natural fractures, including seismic faults, which are one of the key challenges in the petroleum industry. It is known that the presence of faults can also lead to development of natural fractures, however relating the faults to fracture occurrence presents subsurface data challenges. Another significant objective aims at deciphering whether these faults are sealed or open during charging and entrapment, and during production and depletion.

In one of the ADCO (Abu Dhabi Company for Onshore Oil Operations) operated assets, a dedicated initiative was taken to cut a core across a seismically visible fault. Formation evaluation logs were run in the well. Image log analysis suggests the core missed the fault by 4-6 feet, however there are a number of anomalous features observed in the core towards the base of the core near the fault. The fracture swarm appears resistive on electric logs. It is not picked well by the oil-based electric log (possibly due to poor pad contact). The density is high along this zone, where a GR spike may indicate mineralization along the fault. The fault strikes NW-SE (N300) with a mean dip of 70 degrees, where no abrupt bed boundary termination or shifts in log response were noted. Formation pressure measurements have been acquired and a difference of around 150 psi was observed across the fault. This suggests that the fault could be sealing, with the possibility of leakage along a few fault bends.

Prior to performing any tests on the core, 360˚ CT-scans of the whole core were carried out. Relevant petrographic descriptions, petrophysical and geomechanical tests were conducted to characterize this faulted interval.

Results

A damage zone with intense fracturing can be clearly seen both in thin sections and core description. From both core description and thin section analysis it was clearly demonstrated that, as expected, intense fracturing occurs closer to the fault, where both open and cemented fractures can be seen. Understanding intensity and location of fractures relative to a fault can be very useful for modeling fracture network models.

Micro-porosity does not occur in the lower most six inches of the core, composed of argillaceous wackestone close to the fault. Micro-porosity also does not occur in the brecciated core zone of the fault, as a result of cementation and digenesis.

Although core sampling has challenges due to core heterogeneity and limited length, comprehensive geomechanical analysis quantified the variation in rock strength along the studied fault. Single-stage triaxial strength tests have been carried out across the faulted core and key rock mechanical parameters, e.g. Young's Modulus, Poisson's Ratio, cohesion and angle of internal friction, were extracted for building a 1D geomechanical model for this well. Variation in rock properties were also observed approaching the fault.

Conclusions

Integrating petrographic, petrophysical and geomechanical characterization helped the asset team to understand the behavior of faults and fractures and relevant changes/variations in rock properties. As fractures/faults play a significant role in reservoir dynamics, understanding their properties with integrated characterization can help the asset team in field development optimization and exploration of unconventional resources. This poster discusses integrated characterization across the faulted rock for reservoir characterization.

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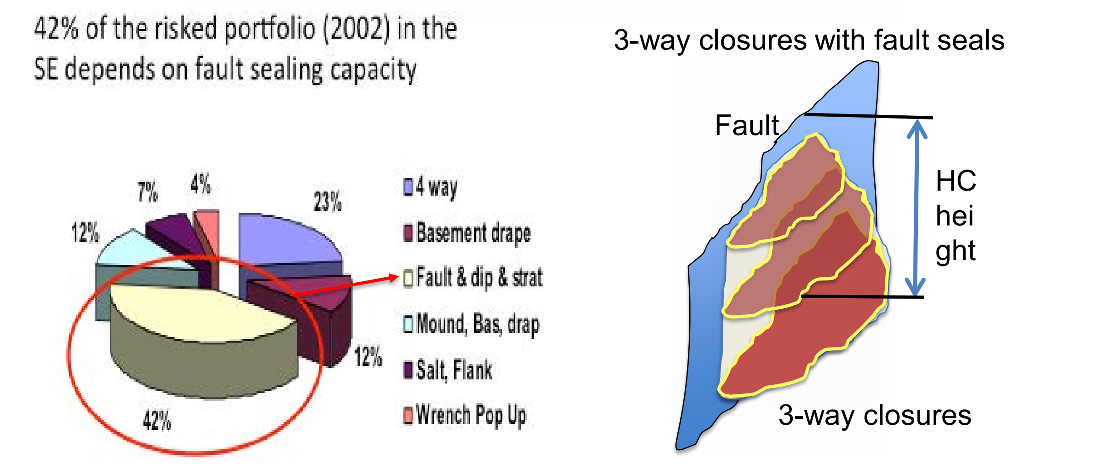
Problem Definition & Objective

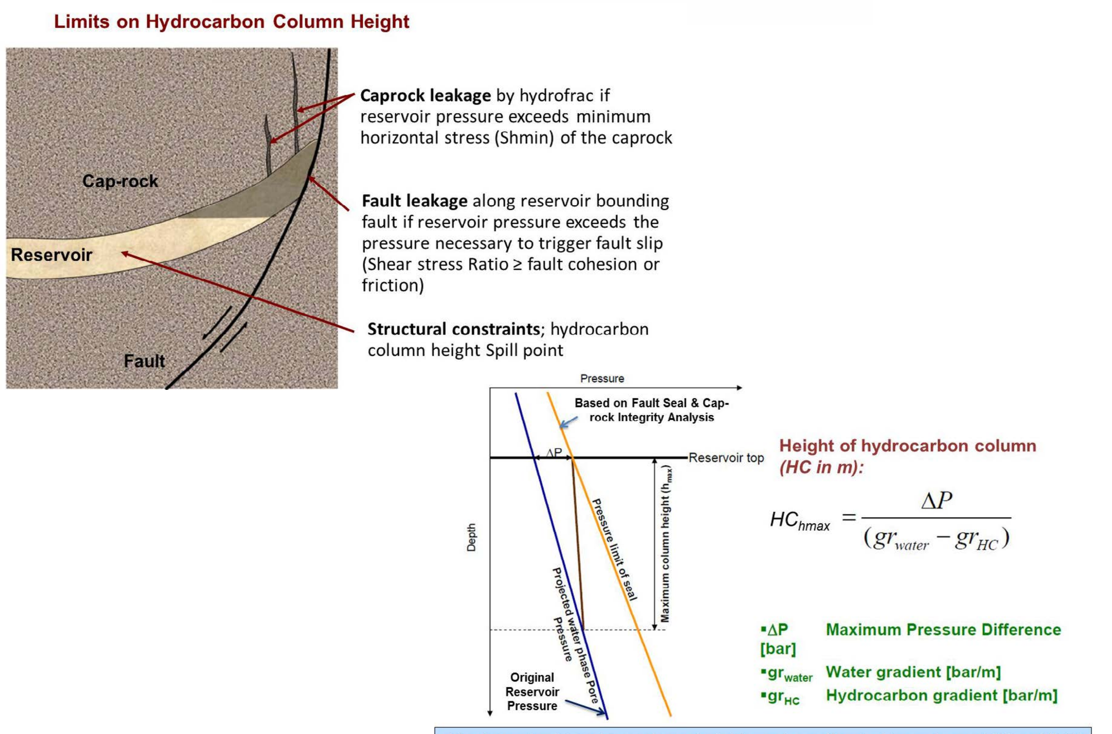
42% of the risked portfolio (2002) in the SE depends on fault sealing capacity



- In exploration, it is essential to estimate HC height (closure) to estimate the volume of hydrocarbon in place
- The built-up pressure by the height of hydrocarbon column (HC), together with the pore pressure and the in-situ stresses control the integrity of both cap-rock and fault seal capacity

The objective is to estimate cap-rock and fault seal capacity that accommodate maximum HC before breach

Hydrocarbon Column Height



$$HC_{hmax} = \frac{\Delta P}{(gr_{water} - gr_{HC})}$$

Maximum hydrocarbon column height can be estimated based on additional fluid pressure required to breach either fault seal or cap-rock.

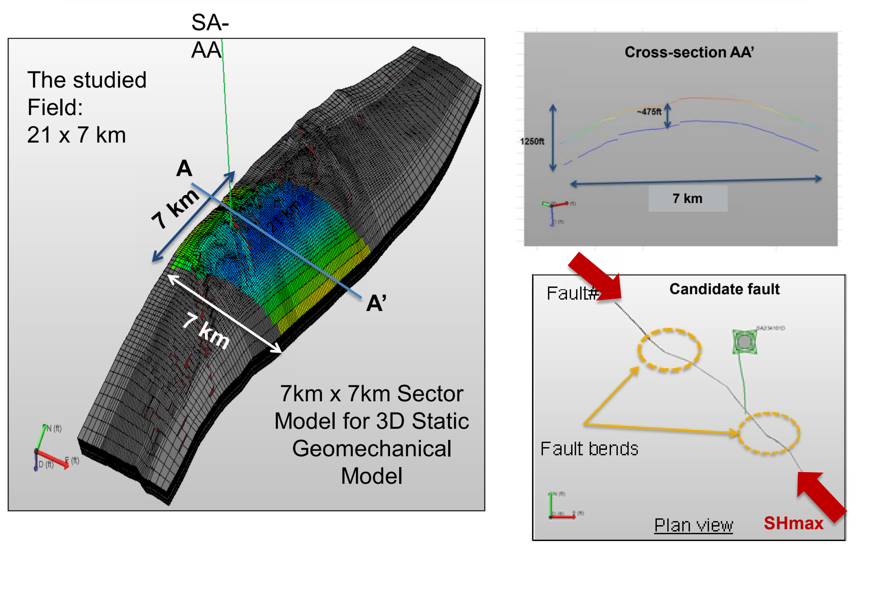
Geomechanical Analyses

- Fault Seal integrity analysis including:
  - Integration of petrography, core & image log analysis
  - Build 1D & 3D geomechanical model using rock mechanics testing results to estimate geomechanical properties of selected seismic faults
  - Estimate state of shear stress along and normal stress at the selected faults under:
    - Normal faulting stress regime
    - Strike-slip stress regime

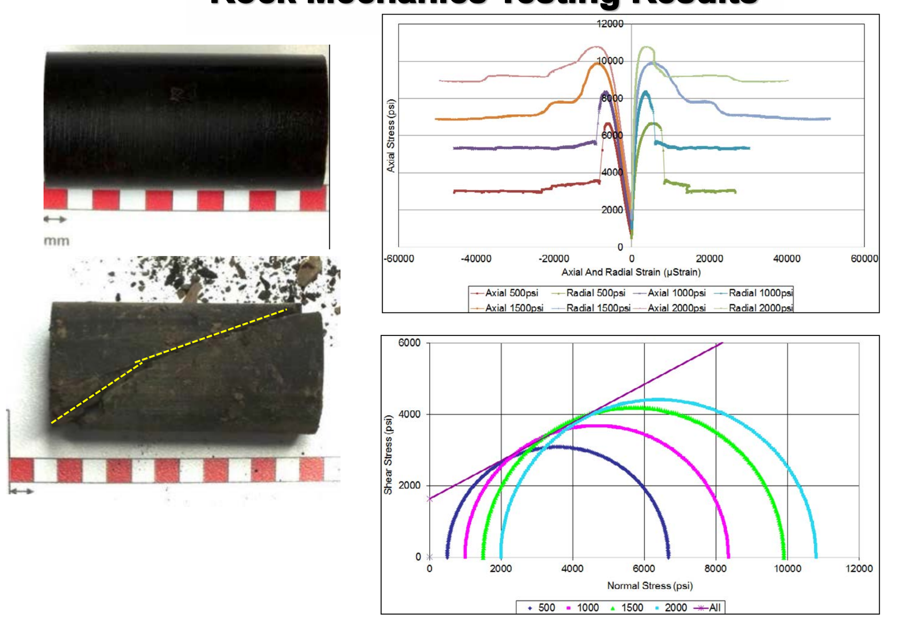
  Taking into account the following possibilities:
    - Assuming three scenarios of dipping planes for the chosen faults as of 60°, 75° and 90°
    - Assuming four scenarios of Shmax directions (300°, 315°, 345°, and 360°)
    - Assuming fill to the spill oil to gas ratio 100:0, 90:10, 80:20 and 60:40

Totally 96 scenarios, which cover possibilities for fault seal

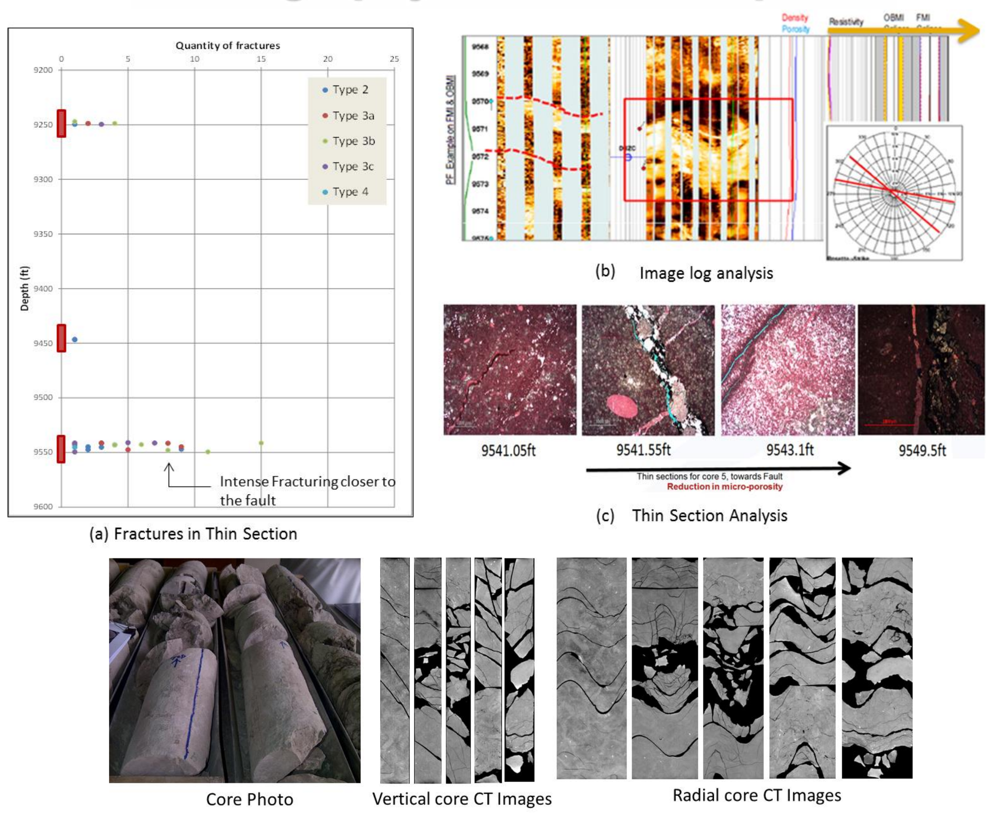
Area of Interest within the Field Structure



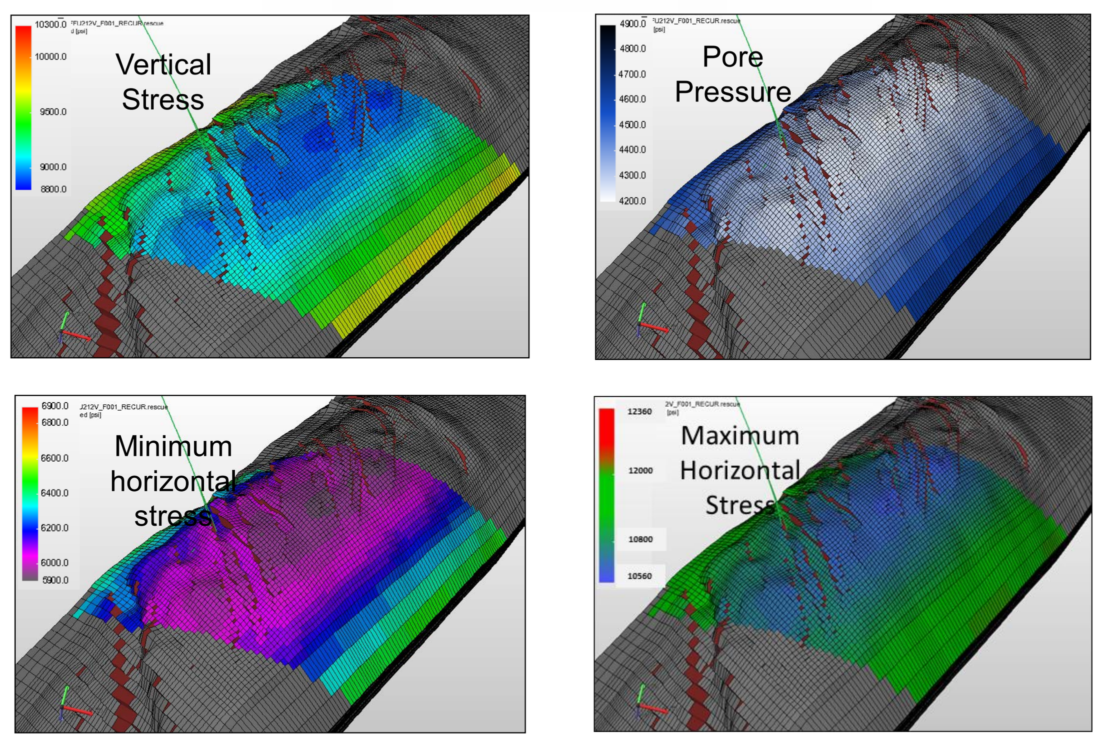
Rock Mechanics Testing Results



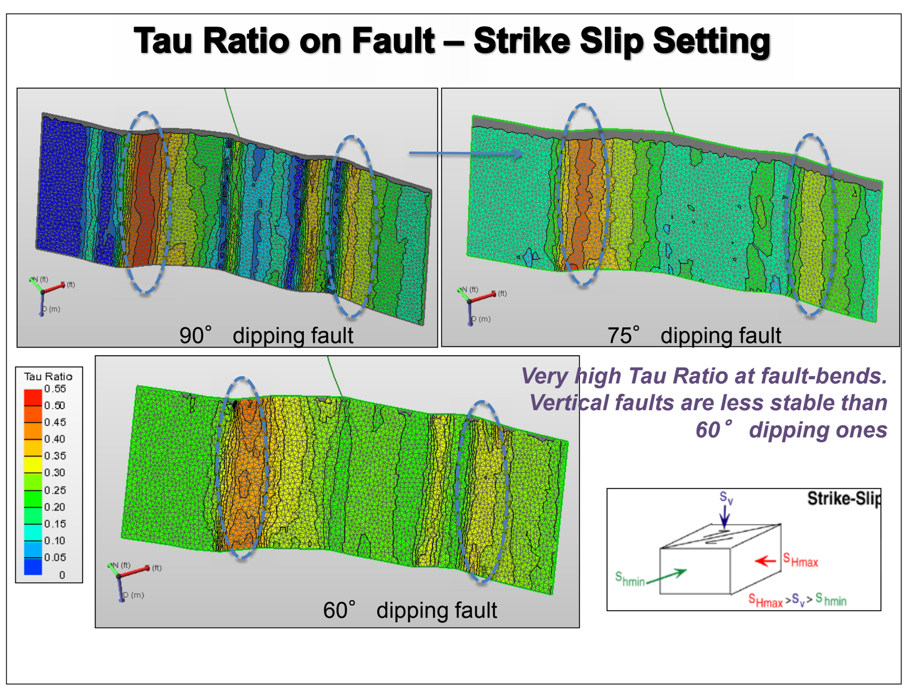
Petrography & Core Description



3D Geomechanical model

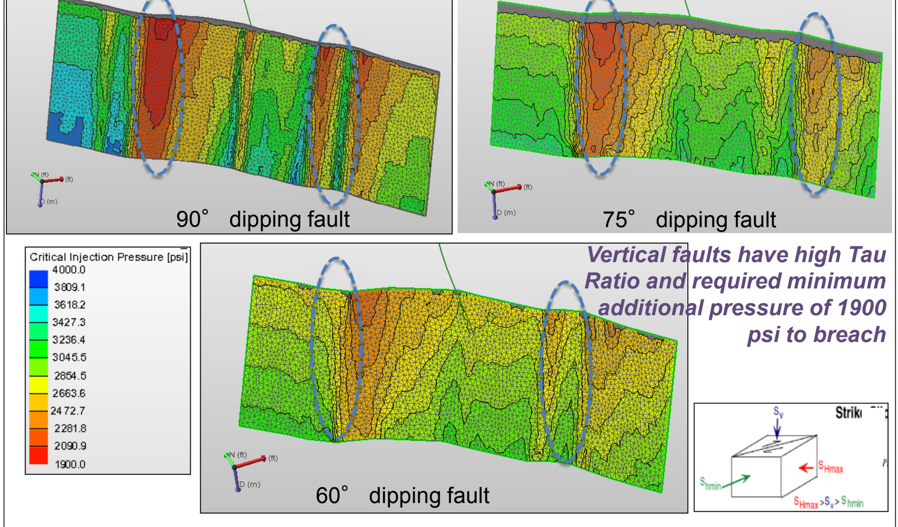


Tau Ratio on Fault – Strike Slip Setting



Very high Tau Ratio at fault-bends. Vertical faults are less stable than 60° dipping ones

Additional fluid pressure (ΔP) required for breaching the Fault Seal



Vertical faults have high Tau Ratio and required minimum additional pressure of 1900 psi to breach

Conclusions & Recommendation

- Reservoirs were filled to the spill and HC height reached maximum structural closure, as both fault seal and cap-rock withheld excess pressure and in-situ stresses by the HC height
- Some portions of the fault seals (fault bends) exhibit further strain due to excess of stresses:
  - Bends in dipping faults exhibit higher strain under normal faulting stress regime
  - Bends in vertical to sub-vertical faults exhibit higher strain under strike-slip stress regime
  - Possible leak might occur locally across very highly strained fault bends
- It is recommended to collect cores across seismic faults to have realistic elastic and mechanical properties of the fault seals
- Accurate estimation of dip magnitude from 3D seismic data is very important to characterize sealing capacity of faults.