Fault Seal Analysis in the Southern Pletmos Basin, Offshore South Africa: Implications for Hydrocarbon Migration and Entrapment*

Sanelisiwe Mhlambi[1], Fritz A. Agbor[1], Tapas K. Chatterjee[1], and Jan van Bever Donker[1]

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[1]Department of Earth Sciences, University of the Western Cape, Cape Town, Western Cape, South Africa (3555622@myuwc.ac.za)

Abstract

The Syn-rift succession encompasses the primary exploration target in the southern Pletmos Basin. Several fault-bounded structural traps that contain gas accumulations have been discovered within this succession. Likewise, ubiquitous residual gas shows have been encountered in most drilled wells. Yet, the impact of faults on fluid flow is poorly understood. Therefore, this study aspires to predict, and where possible, quantify fault seal integrity and sealing capacities of some of the major prospect-bounding faults. A multi-disciplinary research strategy was employed to fulfil the study objectives. Fault mapping and geo-cellular modelling using geostatistical algorithms were undertaken to provide the basic geometric and structural input for more advanced fault seal analysis applications. Juxtaposition analysis was carried out to identify zones with a high probability to seal (or leak) and as the first-order tool for predicting fault seal potential. Threshold pressures, hydrocarbon column heights, cross-fault permeability, and transmissibility were used to estimate the sealing capacities of the faults. In addition to juxtaposition and customary fault-rock properties, the study also analyzed parameters that can be deemed to be representative of cross-fault fluid flow (i.e. effective cross-fault permeability and transmissibility: ECFP and ECFT). Finally, modelling of the geo-history facilitated the validation of the properties that underpinned fault seal analysis studies. The Ga-Q and proposed Ga-K prospects along with their main bounding faults formed the foci of the fault seal analysis results. The analyzed faults showed excellent initial sealing potential due to either favorable juxtaposition or shale gouge development. Nonetheless, predicted hydrocarbon column heights and threshold pressures were low suggesting that the seal integrity of the analyzed faults is predisposed to failure. In addition, high predicted fault permeability and transmissibility values signify the presence of open and permeable

fracture networks within the fault zones. Thus, it is proposed that the faults are very likely to have leaked during hydrocarbon migration and filling of traps resulting in empty or under-filled hydrocarbon reservoirs.

Selected References

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‘Fault Seal Analysis in the Southern Pletmos Basin: Implications for Hydrocarbon Migration and Entrapment’

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[1]Department of Earth Sciences, University of the Western Cape, South Africa

Outline

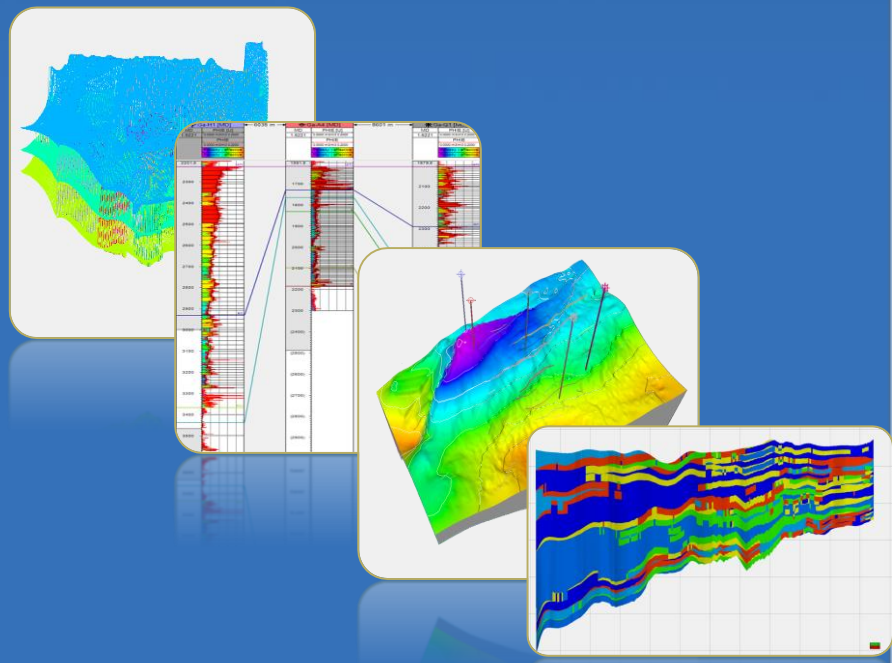
- Executive Summary
- Study Objectives
- Overview of the Pletmos Sub-basin
- Research Methodology
- Results
- Conclusions

Executive Summary

- 1000 km² 3D seismic survey acquired to cover the Superior High (most prospective subsurface feature).
- Variety of frontier plays each with materially significant upside potential identified;
  - Proven: Fractured & sub-aerial quartzite Table Mountain Fm. (Ordovician - Devonian Cape Super Group) and draped sands on syn-rift structural high.
  - Unproven: Barremian basin floor fan and channel (e.g. Sable, Oribi and Oryx)
- What is the problem?

Study Objectives

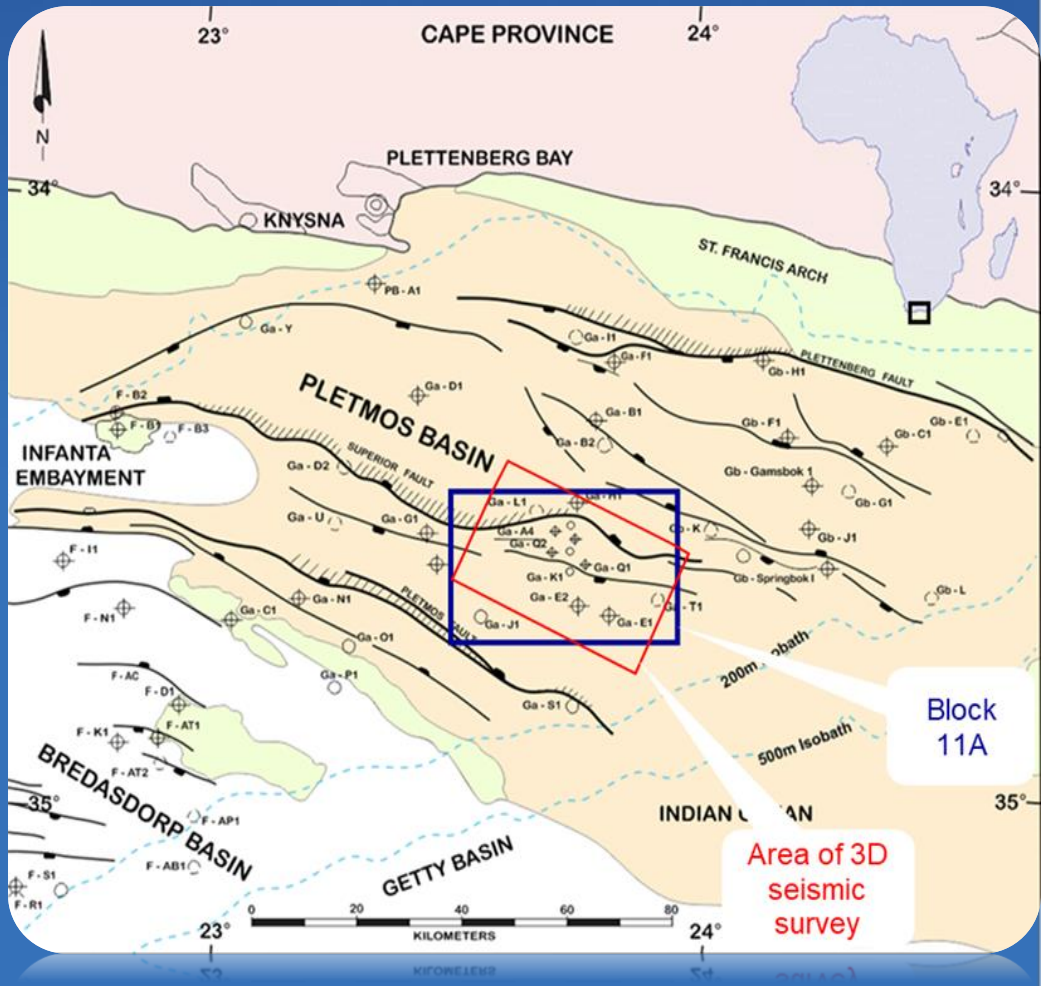
- To evaluate whether fault seal failure played a role in the failed exploration efforts in the basin, and
- Explore the effects on the viability of the unproven Ga-K prospect.
- Summary of workflow:
  - Structural Interpretation
  - Petrophysical Evaluation
  - Geo-cellular Modelling
  - Fault Seal Analysis



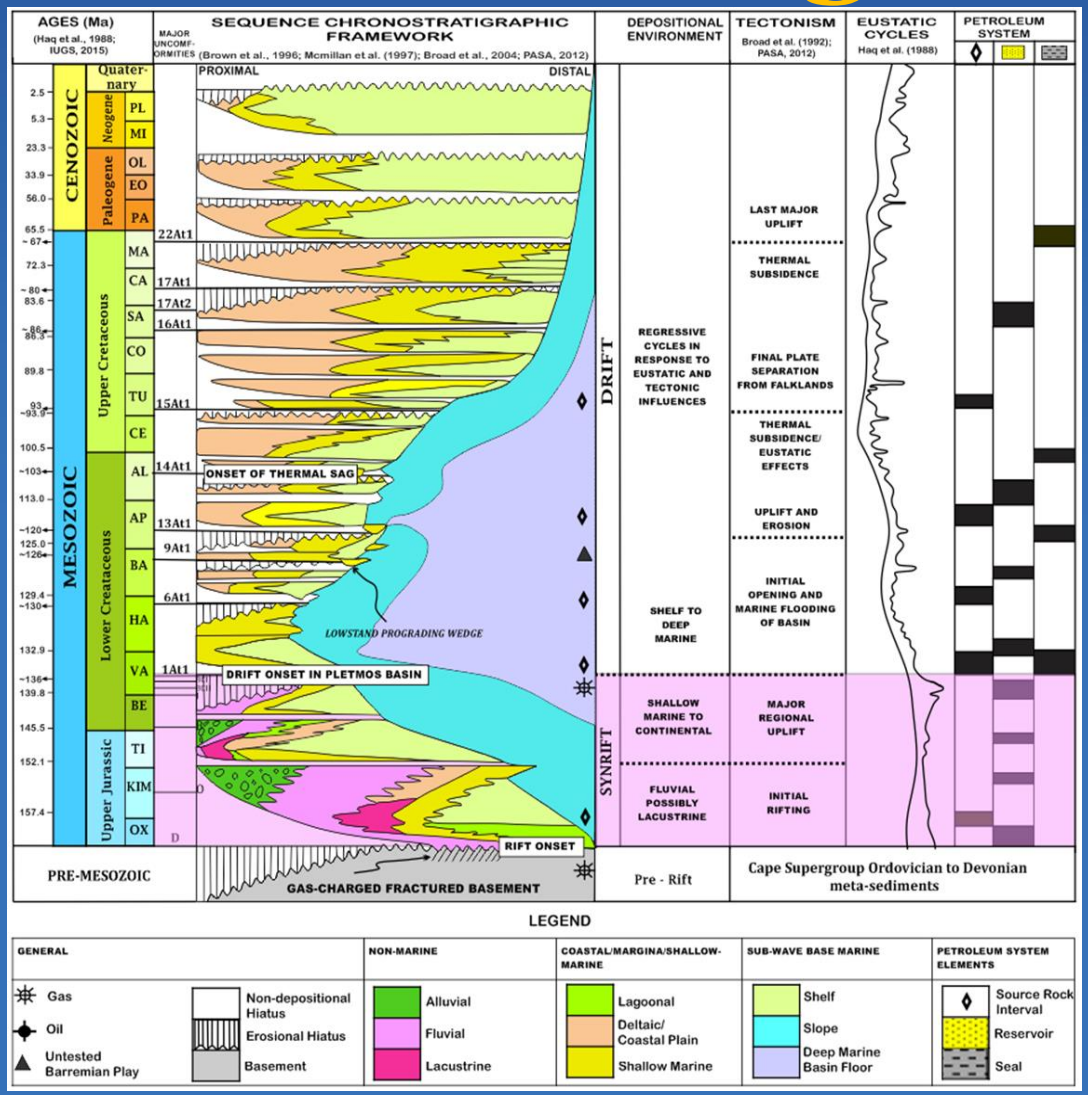
Pletmos Sub-basin

Overview

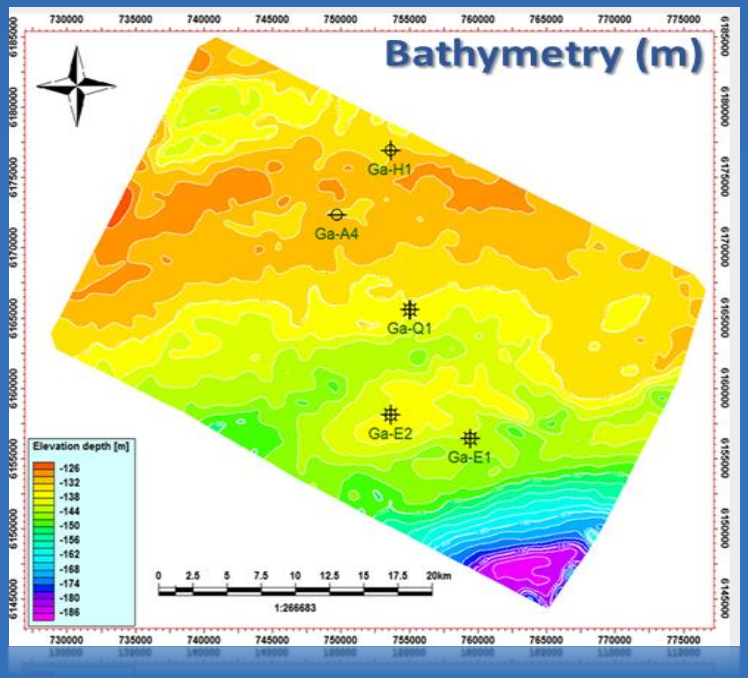
- One of five sub-basins situated in the Outeniqua Basin.
- Basin type: Intra-cratonic rift basin.
- Sedimentary thickness: 7 km.
- Water depths: Shallow; southern boundary ~ at the 200 m isobath.
- Areal extent: 13 300 km².



Geologic History



- Syn rift, transitional-early drift and late drift phases recognized.

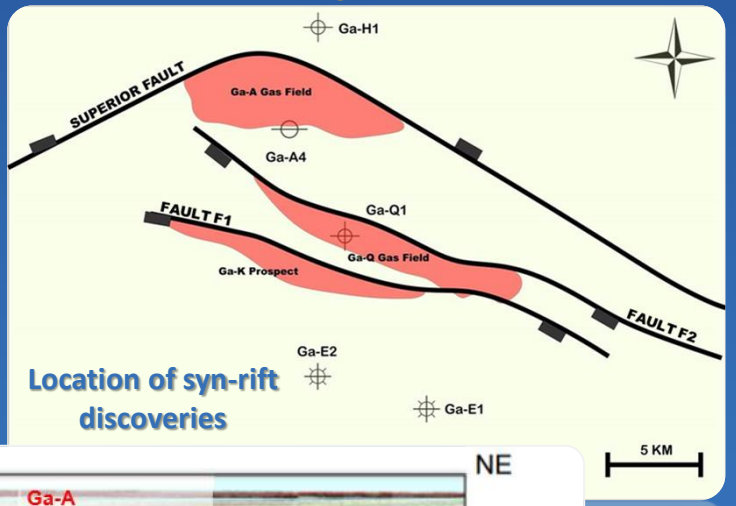


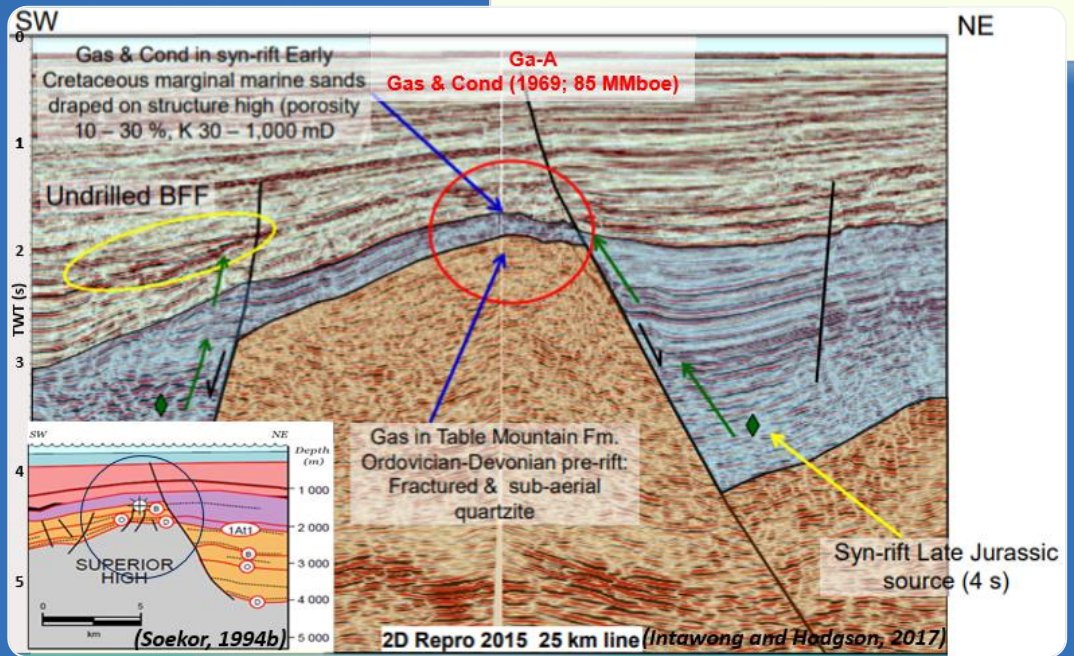
Exploration History

Proven petroleum system(s)

Main source rocks:

- Syn-rift Kimmeridgian lacustrine mudstone.
- Valanginian-Hauterivian restricted marine mudstone.
- Aptian anoxic restricted marine mudstone.
- Turonian inner shelf mudstone.





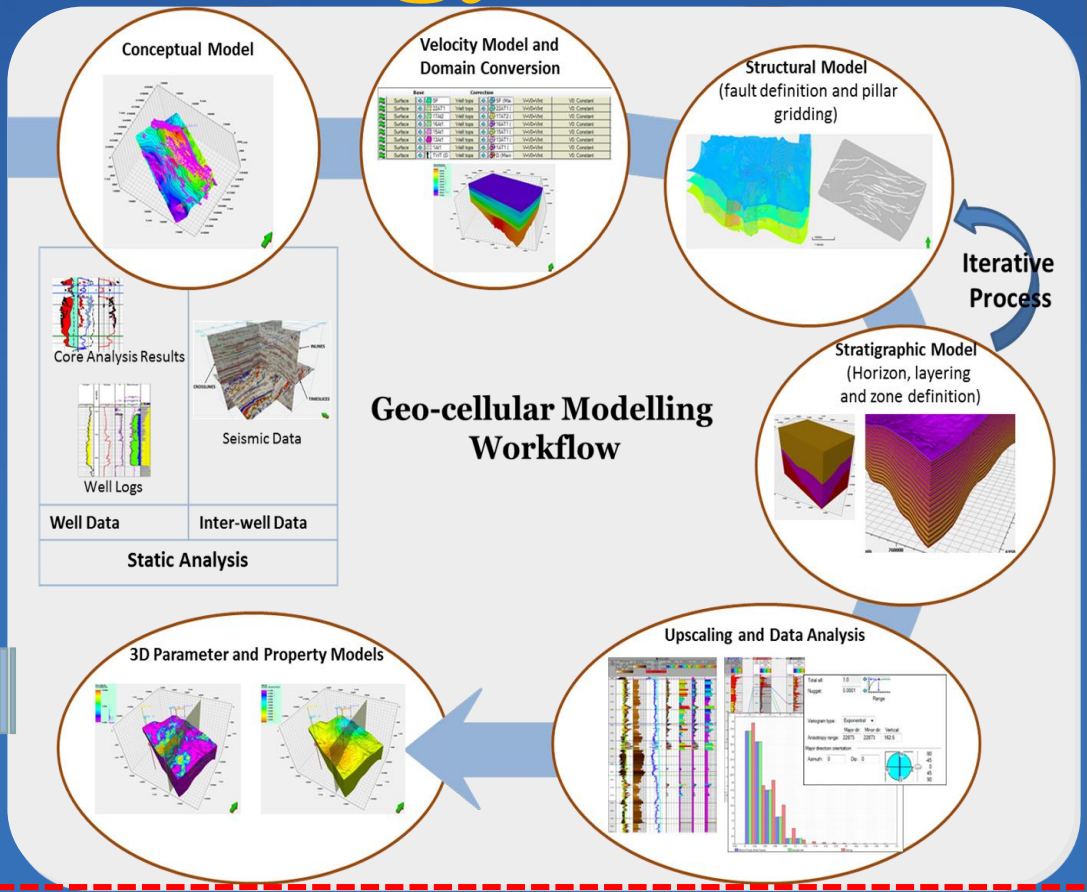
Methodology

Summary of workflow covered by this study

Fault Properties

- **Fault juxtaposition**
- **Clay content prediction**
- **Threshold pressure and hydrocarbon column height**
- **Fault permeability and transmissibility multipliers**
- **Effective cross fault permeability and Transmissibility**

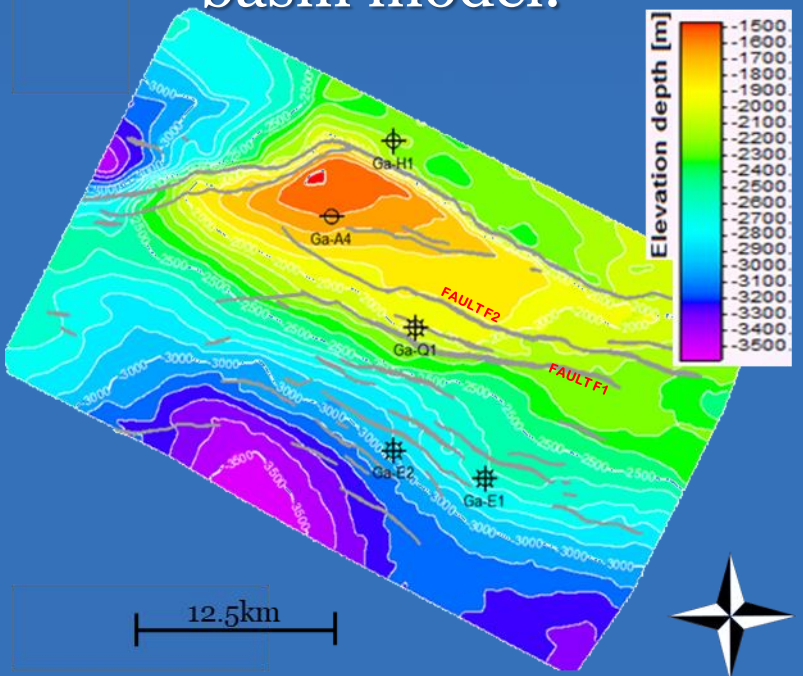
Fault Seal Analysis

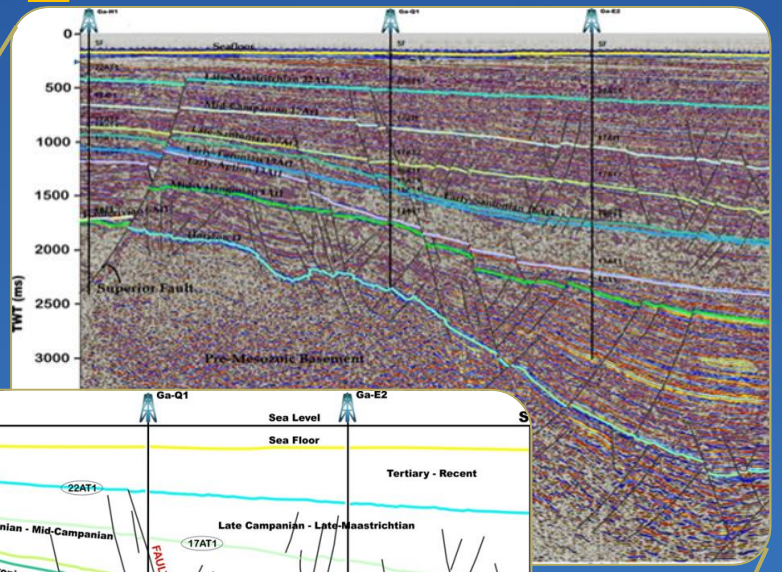


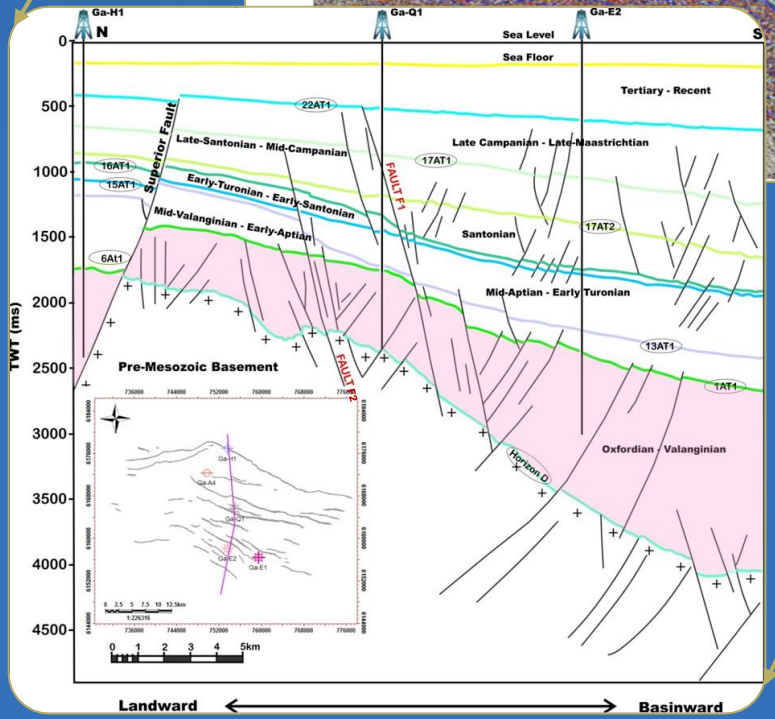
Dynamic Simulation

Structural Interpretation

- Depocentre bounded by northwest to southeast striking fault systems.
- Only regional faults incorporated into the basin model.

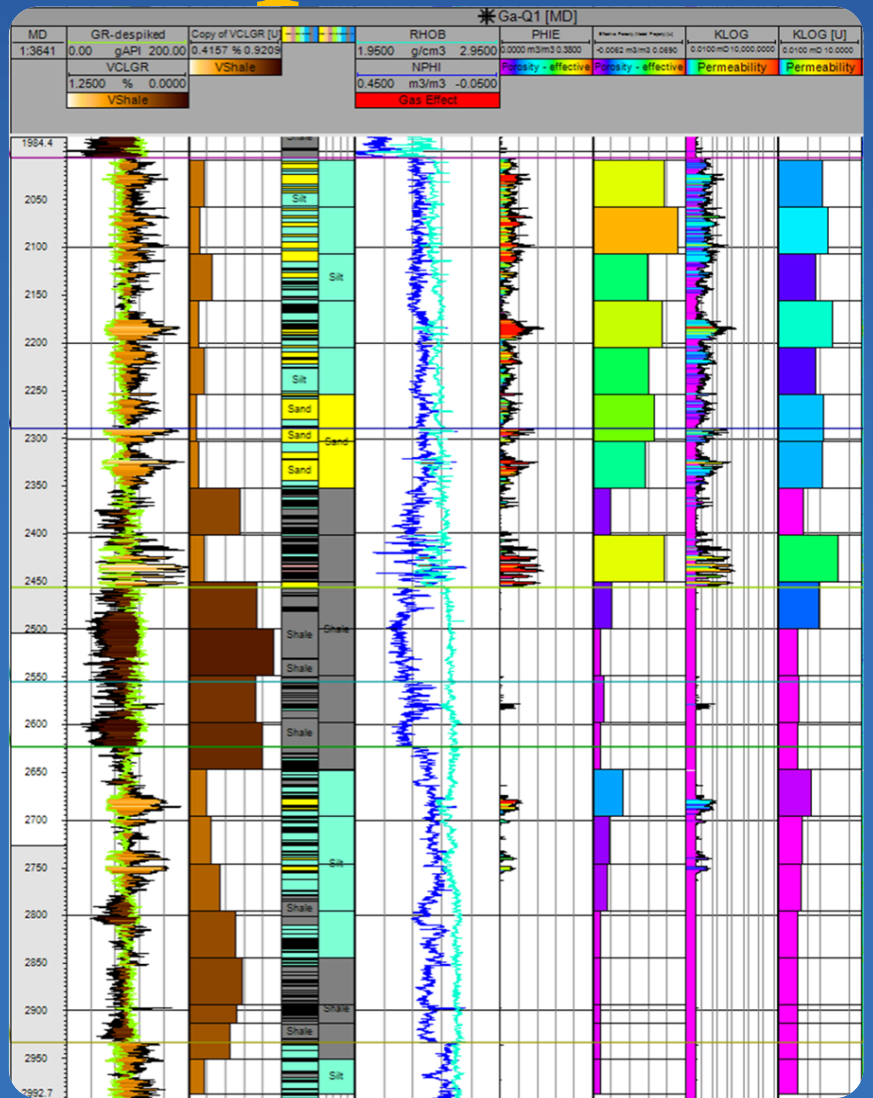




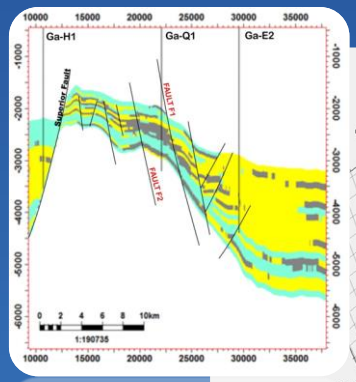


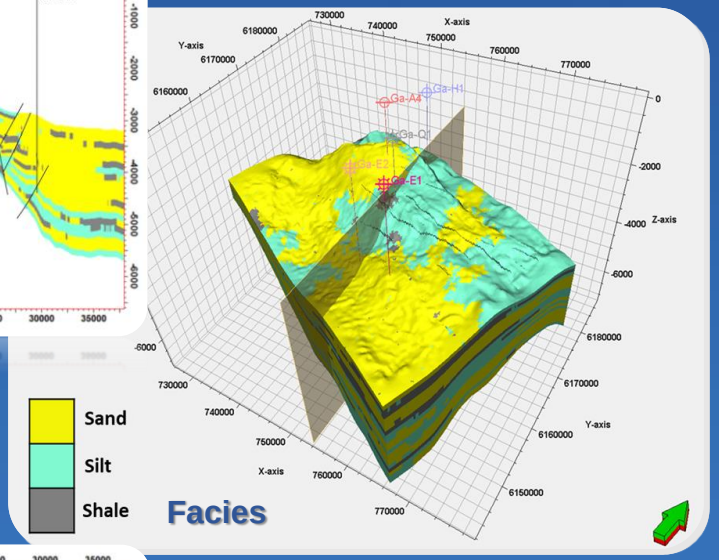
Reservoir Properties

- Main reservoir section delineated below 1At1 unconformity;
  - Sand intercalated with silt and clay
  - No gas effect detectable on the neutron and density logs.
- Φ = 11 – 18%
- K = 1 – 10 mD

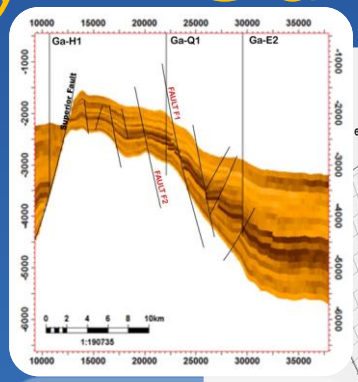


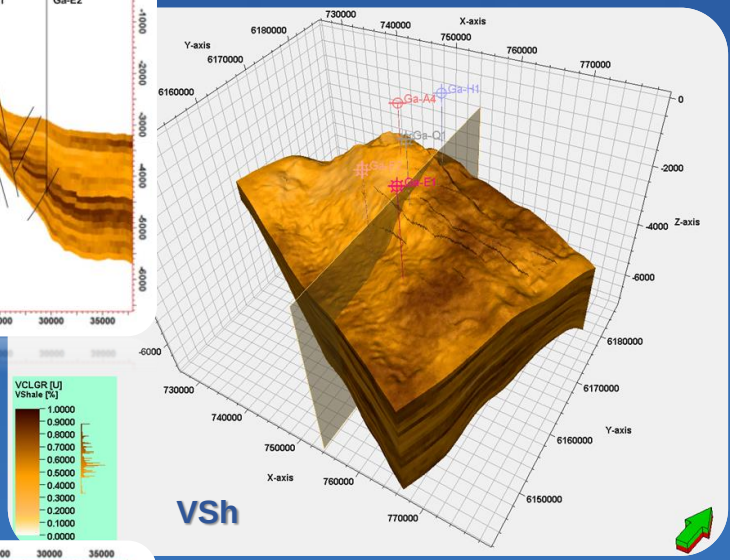
Property Models



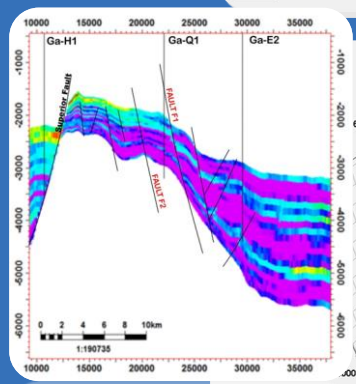


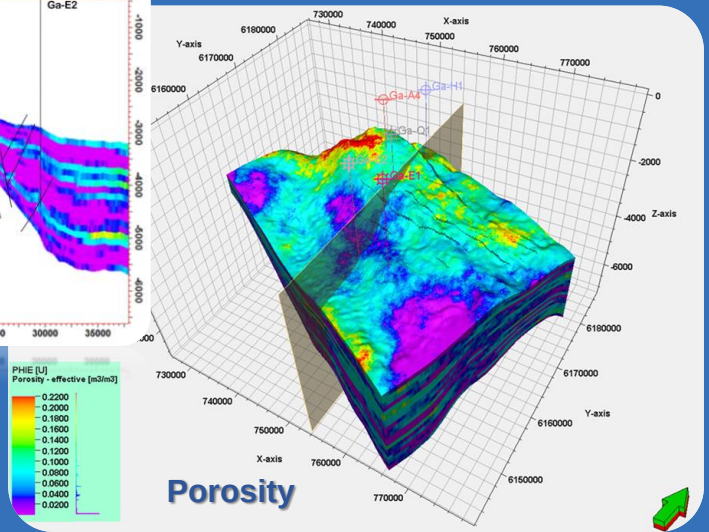
Facies



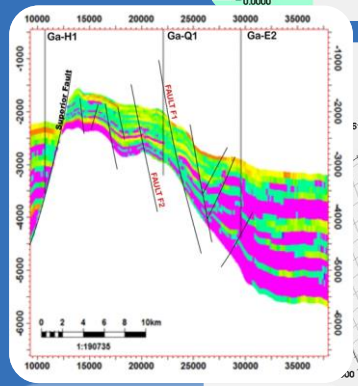


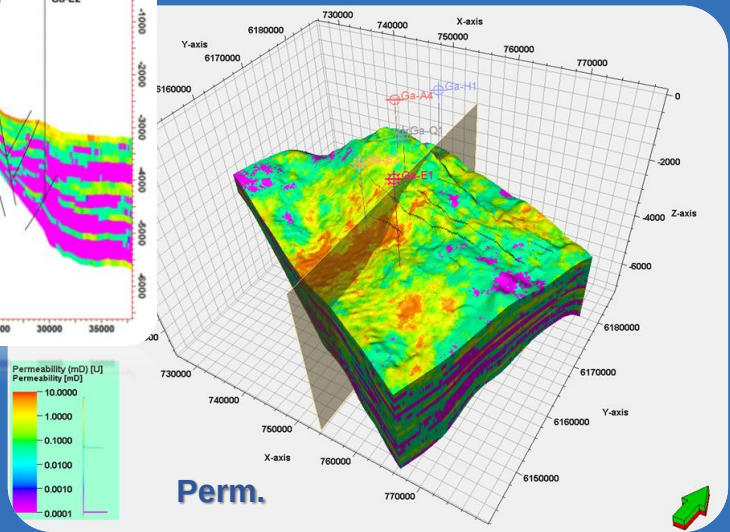
VSh





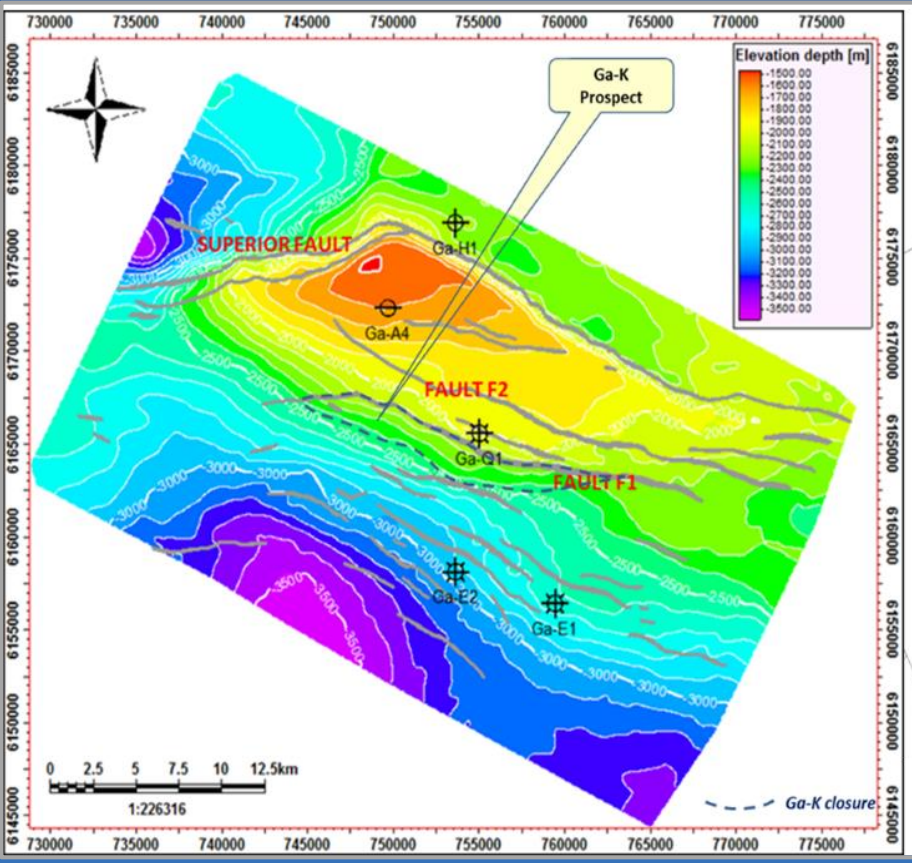
Porosity

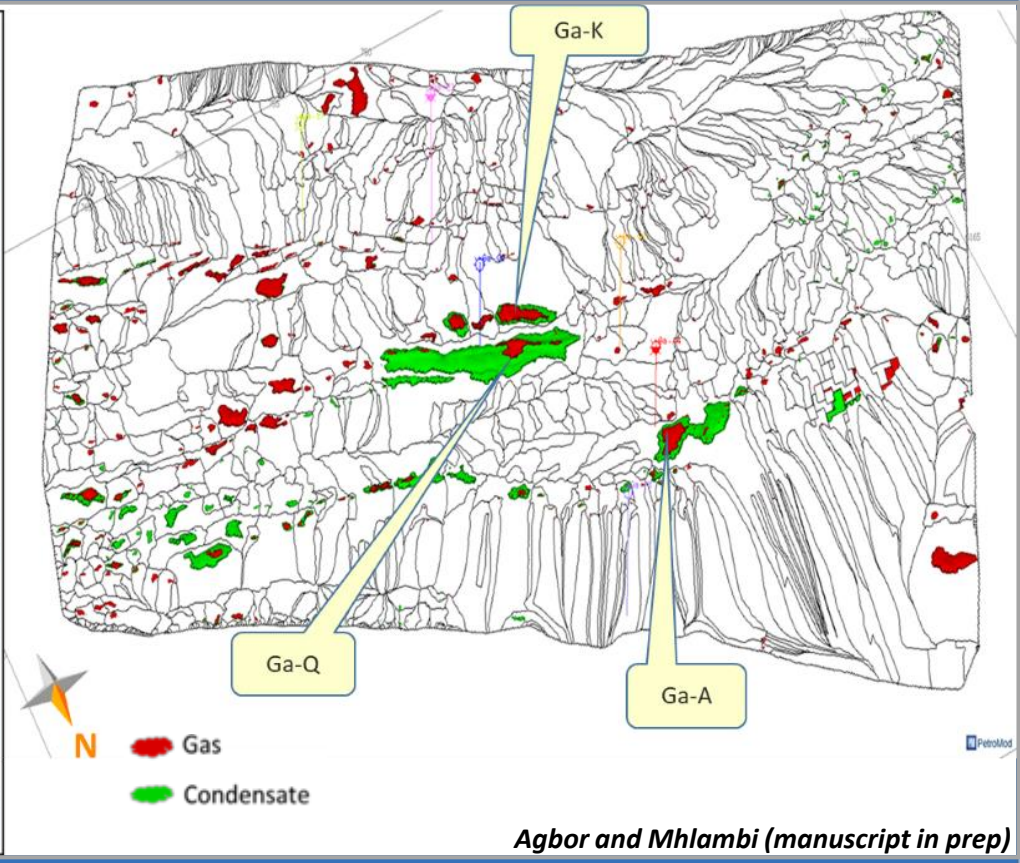




Perm.

Charge Prediction



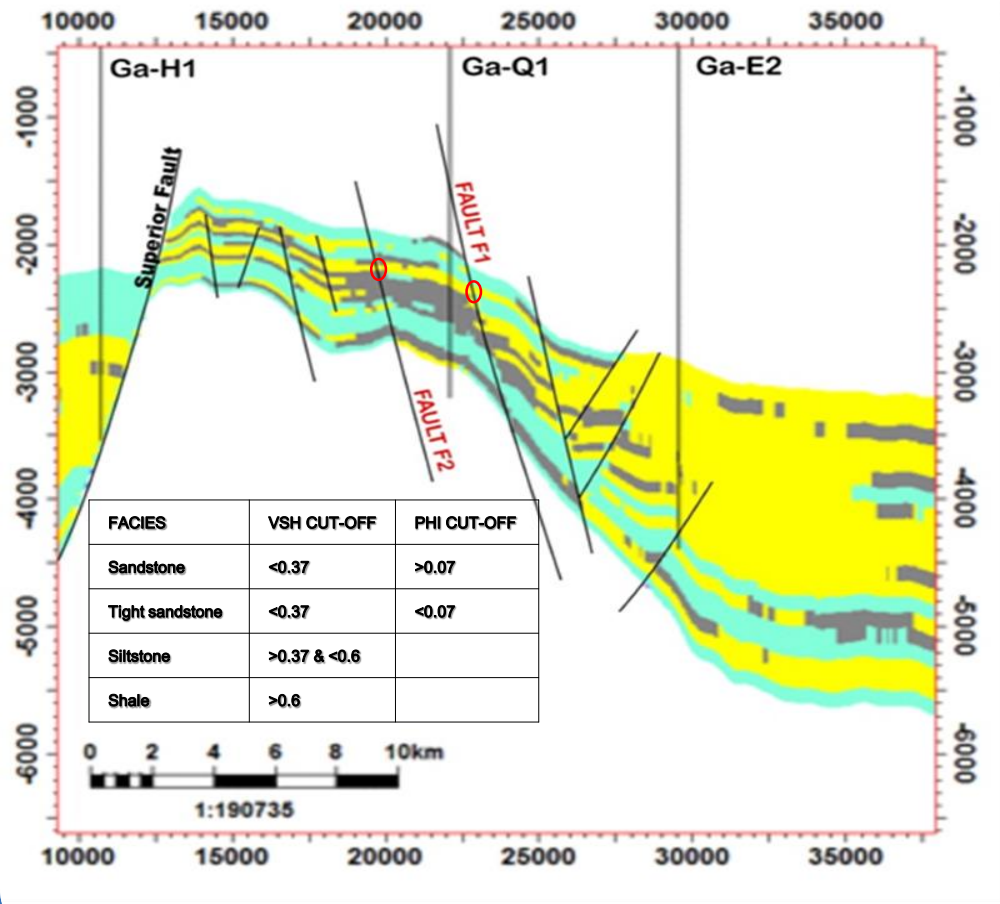


Agbor and Mhlambi (manuscript in prep)

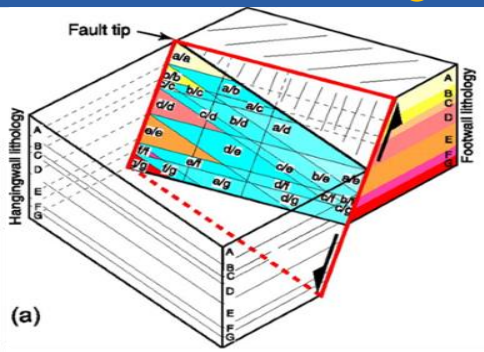
- Model predicts sufficient charge at Ga-A, Ga-Q and Ga-K locations!

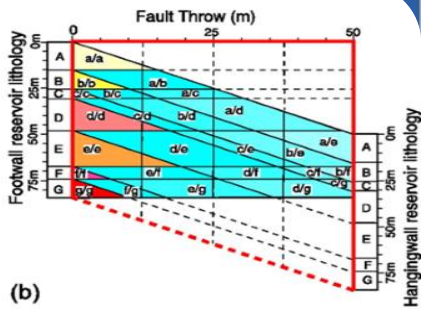
Juxtaposition Analysis

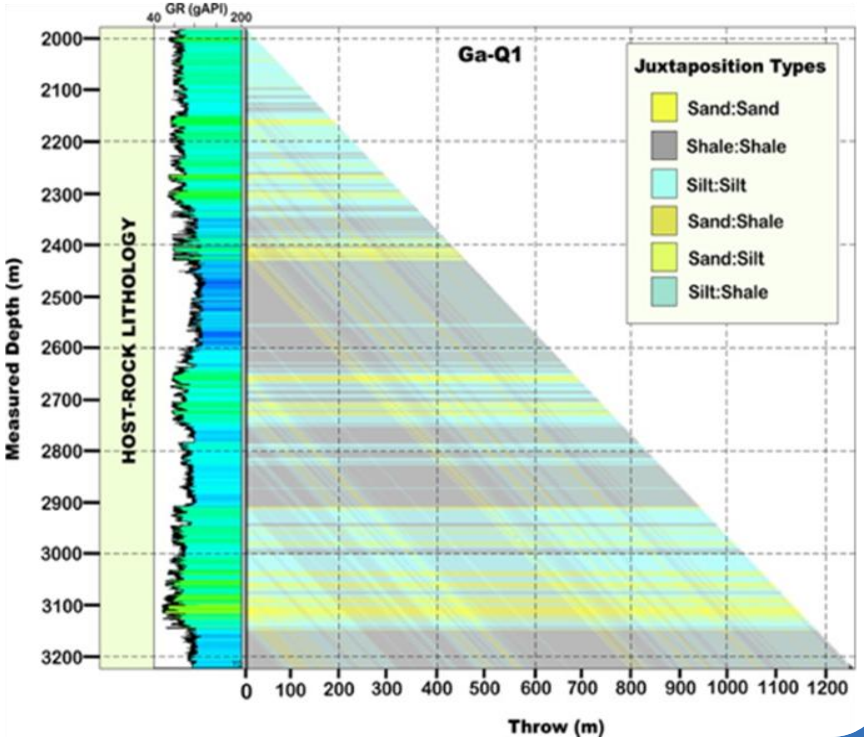
Rapid modelling of seal distributions possible



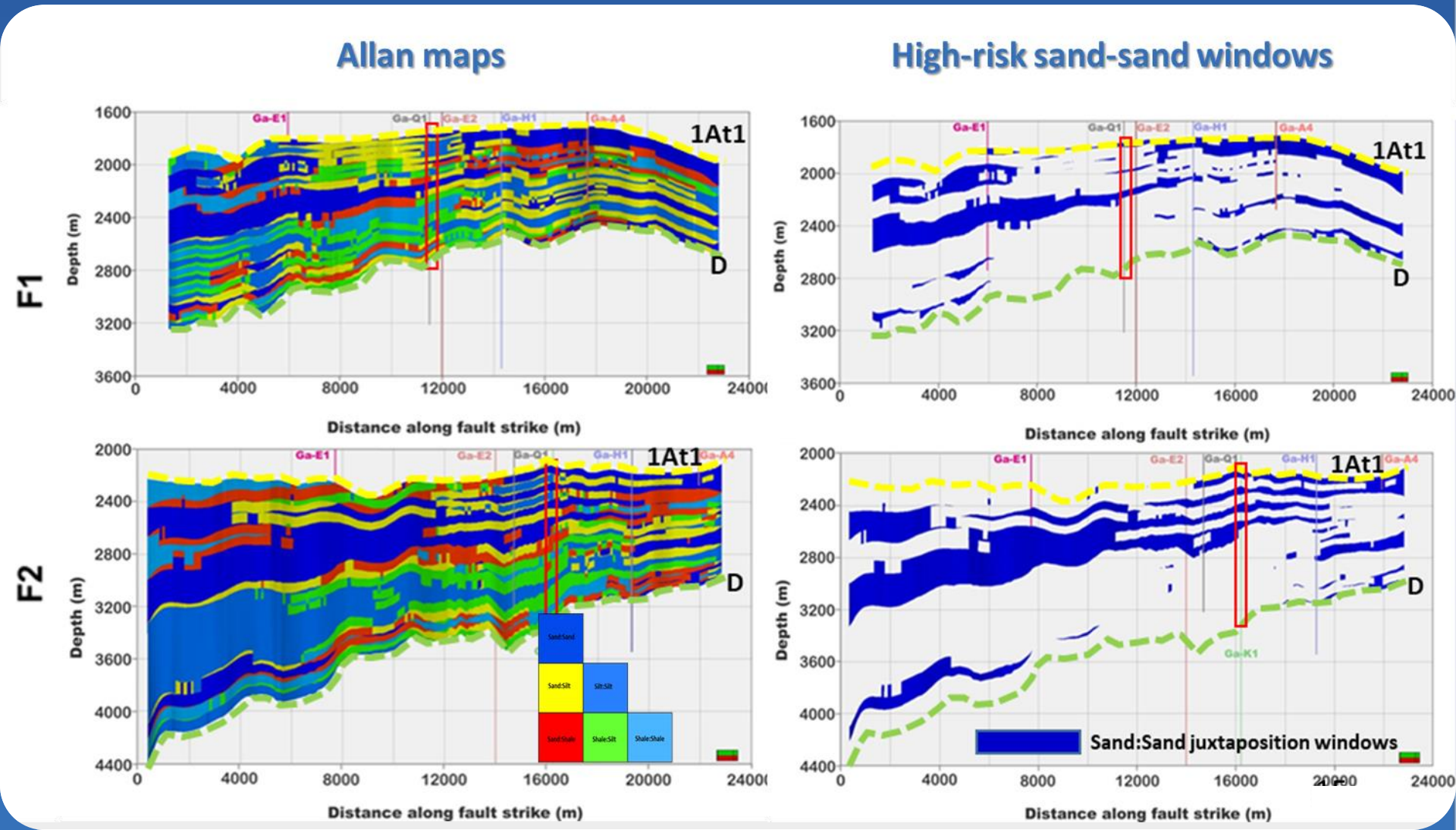
FACIES	VSH CUT-OFF	PHI CUT-OFF
Sandstone	<0.37	>0.07
Tight sandstone	<0.37	<0.07
Siltstone	>0.37 & <0.6	
Shale	>0.6	



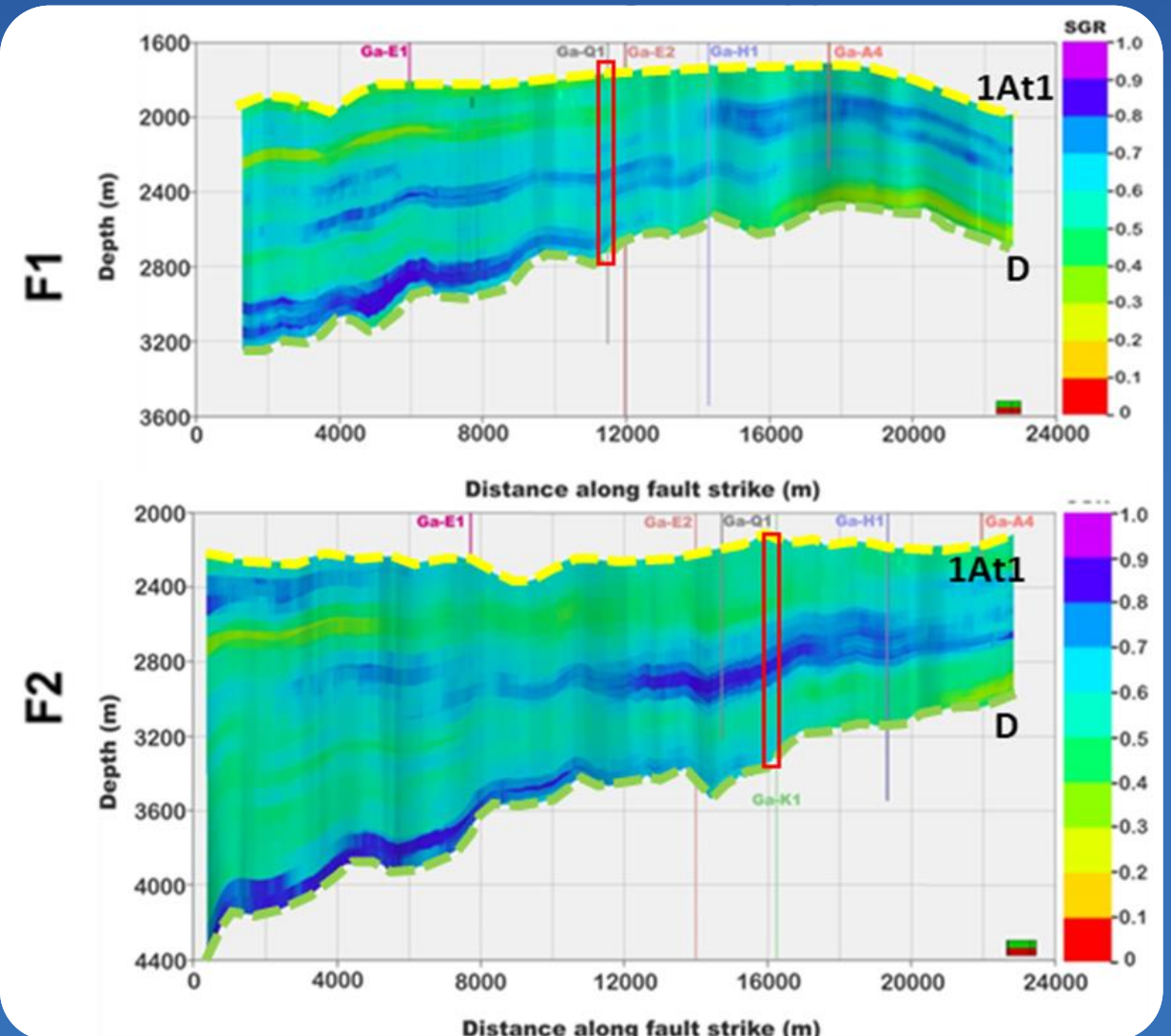




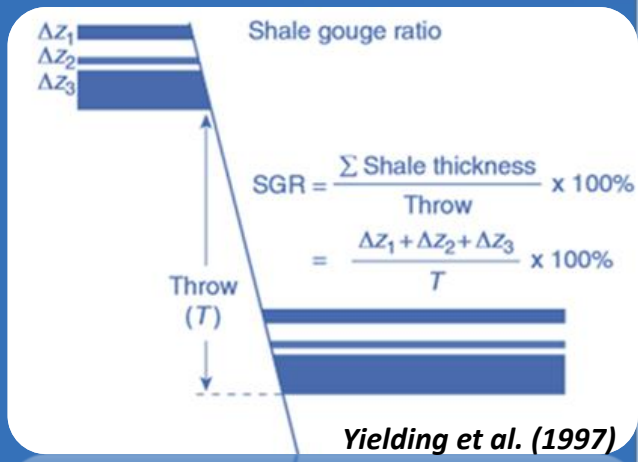
Stratigraphic Juxtaposition



Shale Gouge Ratio

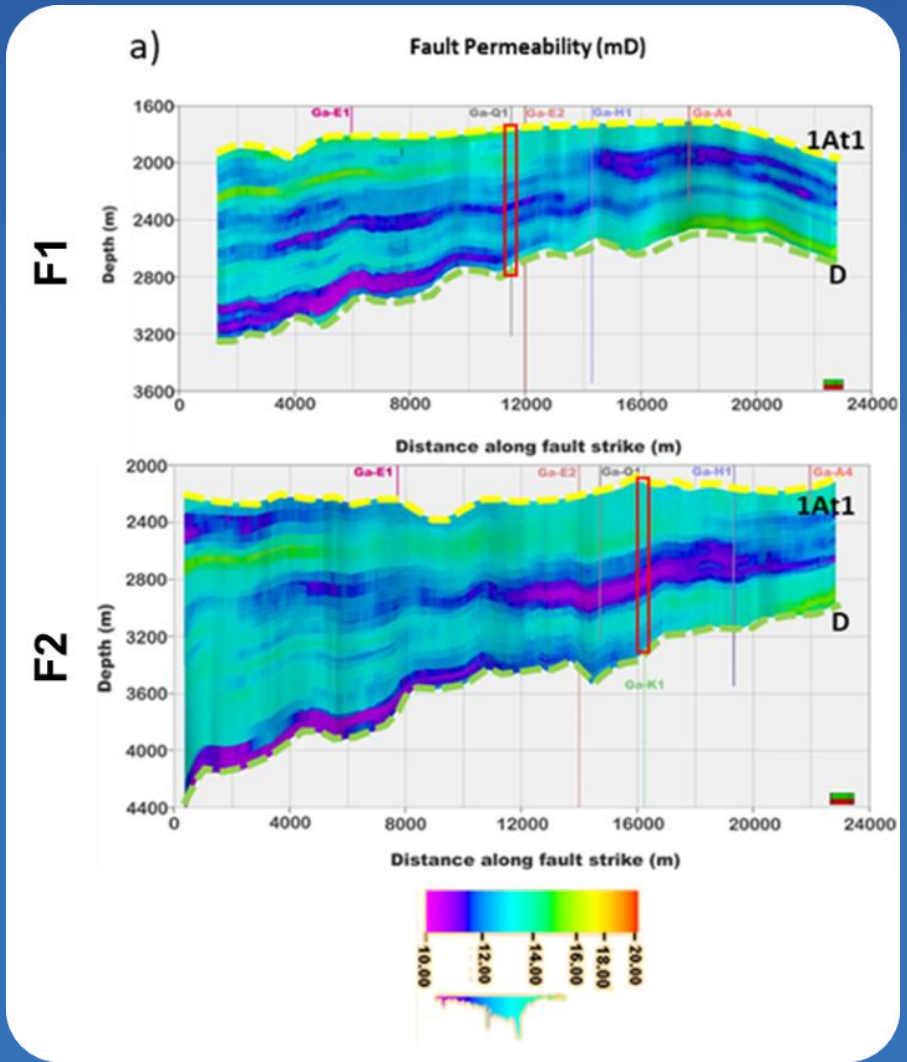


- The SGR is the percentage of shale or clay in the slipped interval.
- SGR>0.3 → High probability to seal.



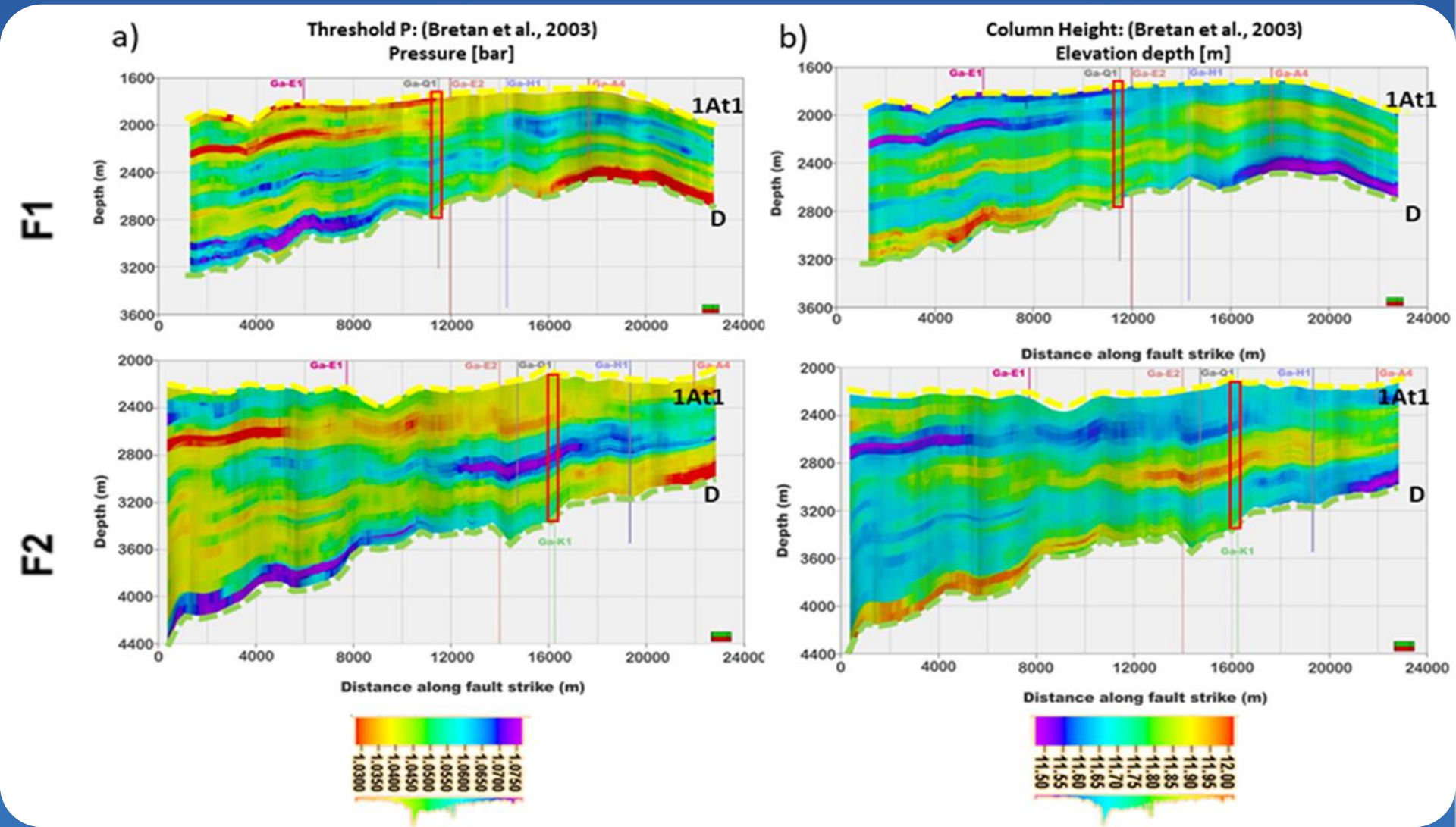
Yielding et al. (1997)

Fault Permeability Prediction

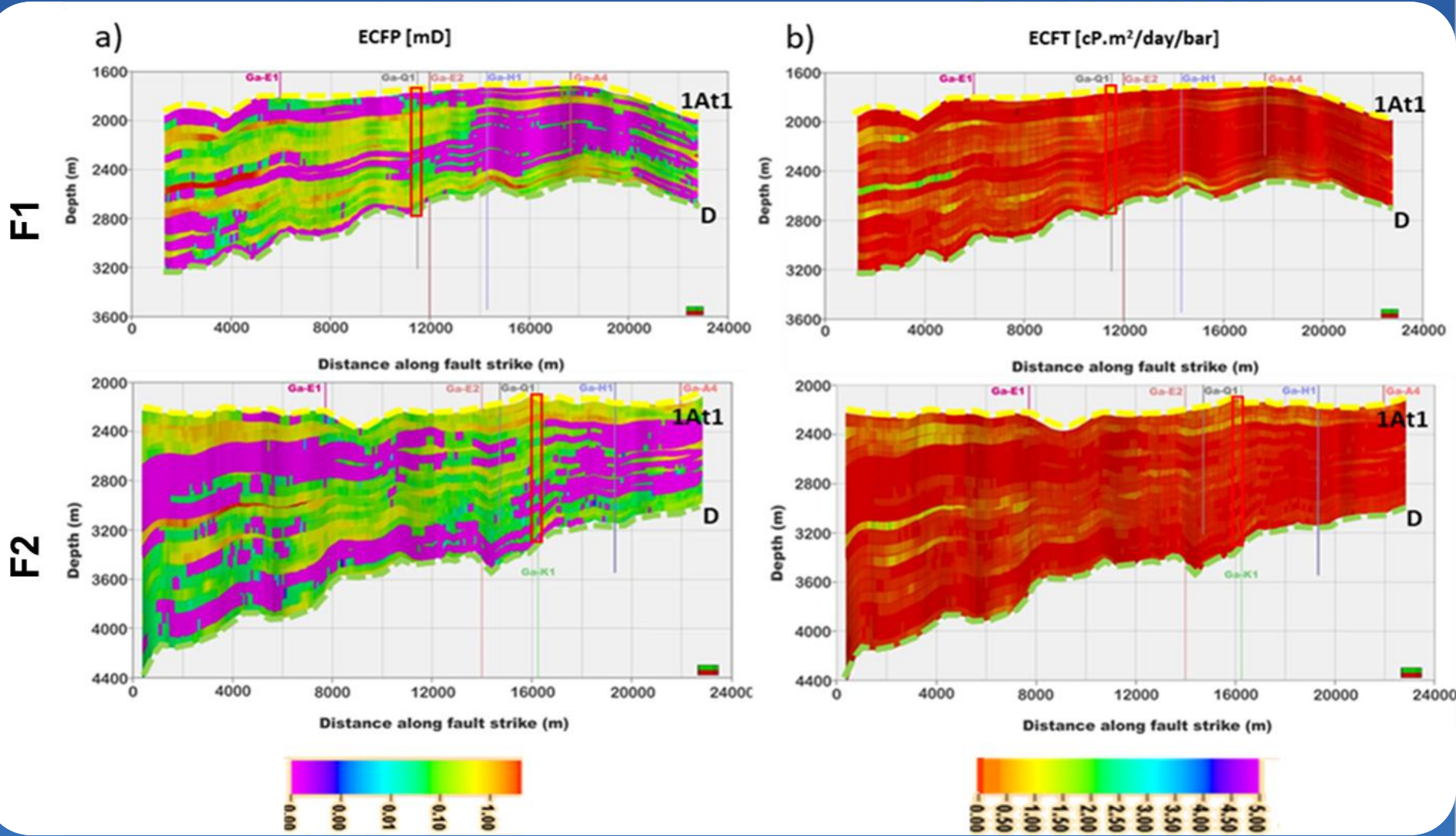


- Based on estimated fault clay content variation.
- Permeability: 10 – 15 mD.
- Permeable fracture networks imply?

Seal Capacity Estimation



Cross-Fault Flow Indicators



Conclusions

- Adequate charge suggested by extant literature.
- Excellent initial sealing potential due to either;
  - Favorable juxtaposition or,
  - Shale gouge development.
- Predicted hydrocarbon column heights and threshold pressures were low;
  - Seal integrity of the analysed faults was predisposed to failure.
- Likeliness of post-charge breach?

Recommendations

- Prospective commercial deposits may lie in;
  - Fractured basement highs (below Horizon D).
  - Reservoir sands above 1At1 – Bredasdorp Basin analogues??

Recommendations for future work:

- Dynamic simulation modelling incl. sensitivity analyses.
- Integrated petroleum systems approach.

"Although the precise role of faults has never been systematically defined, much has been written that touches on the subject. One thing is certain: we need not try to avoid them."

-Frederick G. Clapp (1929)