Case Study of a Tight Gas Reservoir Offshore South Africa: Its Significance in Exploration and Exploitation*

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Abstract

The recent development of an “unconventional” tight gas reservoir offshore South Africa has brought to the fore many challenges faced by an operator. The reservoir is highly compartmentalized, has low porosity and permeability under high temperature and pressure (HPHT) conditions, comprising of tidally-influenced shallow marine deposits varying from amalgamated sandstone to heterolithic facies. Average reservoir porosity and permeability is 9% and 1mD respectively. The presence of diagenetic secondary porosity caused by leaching and preserved by overpressure has led to the development of high poro-perm streaks, where porosity reaches up to 16% and permeability 100mD. The reservoir is deep, having been buried below 3600m. The reservoir is very competent with UCS values of 35000psi.

The challenges associated with such reservoir properties make for harsh drilling conditions and complex development solutions. Numerous studies were done, and solutions executed to better understand and combat the challenges faced while developing the field, beginning with the completion design. Encouraging tests from seven appraisal wells could not solely guarantee a sustainable gas rate over production time, inducing the execution of an array of completion strategies to overcome this challenge. Three production wells were drilled with a long horizontal section, over 1500 m in length, each with a different completion strategy; Well A: un-cemented and perforated, Well B: slotted liner, Well C: barefoot. All wells were drilled parallel to the maximum stress direction with the aim of maximizing wellbore stability. Even with the implementation of multiple completion methods, the challenges posed by the field continually required improved understanding to wholly interpret the drilling and production results. Numerous quantitative analyses were carried out to better characterize the reservoir, stratigraphy and structural compartmentalization as well as the enhanced poro-perm distribution. The choice of drilling mud was recommended based on an analogue field extracted from a database of tight gas reservoirs, and a real-time geosteering approach assisted in well placement. Even with all these measures in place, more is needed to fully realize the potential of such a field, opening the opportunity to unlock immense resources of similar character.

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Field Development Challenges

- Heterogeneity (G&G data integration, and active geosteering)
- Highly faulted & compartmentalized (Long-reach horizontal wells considering stress regime)
- Tight Reservoir (Completion strategy)
- Formation Damage, HPHT & Operational Impact on NPT (Mud choice)
- Well Performance

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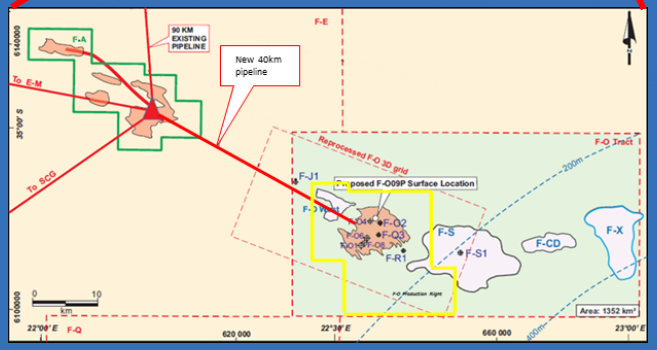
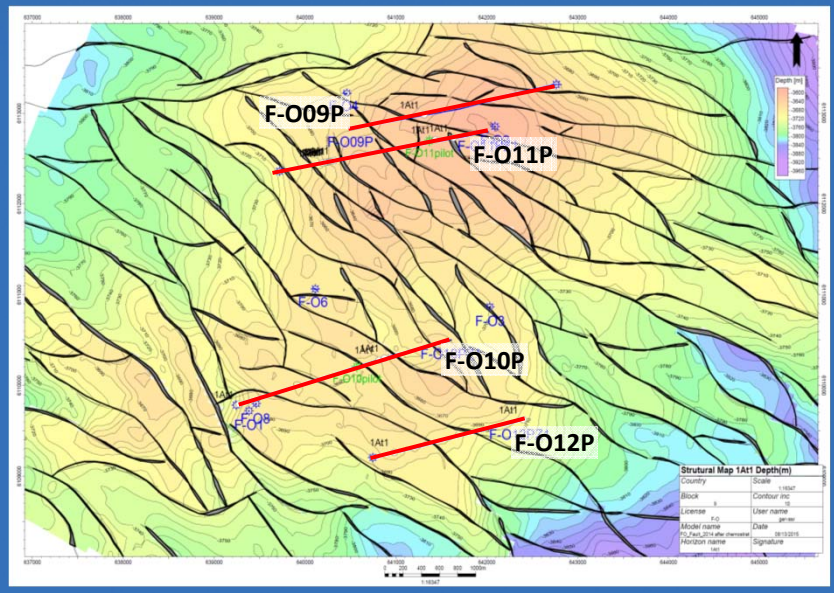
Location & Well Summary



Location map of the F-O Gas Field

- Location
  - F-O is a producing field located 400km south-east of Cape Town
  - The field is tied to an offshore platform via a 40km pipeline
- Six appraisal wells drilled in the field (including discovery well)
- Three horizontal producers & one pilot well were drilled as part of the Field Development



Top Structure Map (Depth)

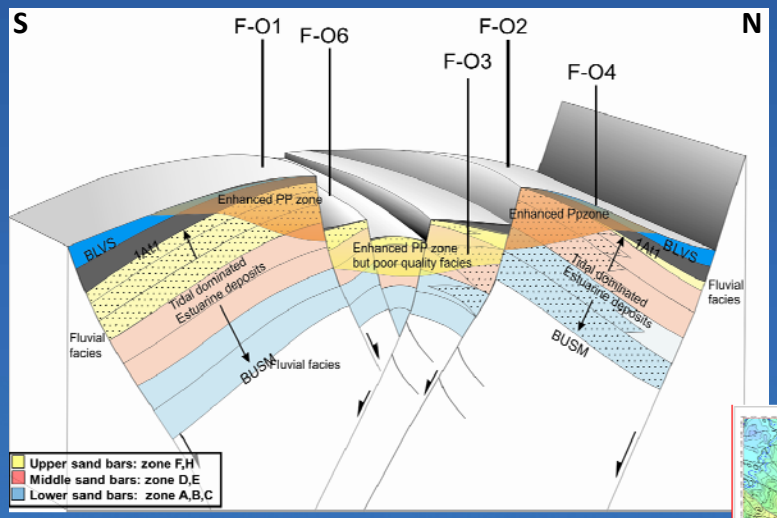
Geological Setting & Reservoir Properties

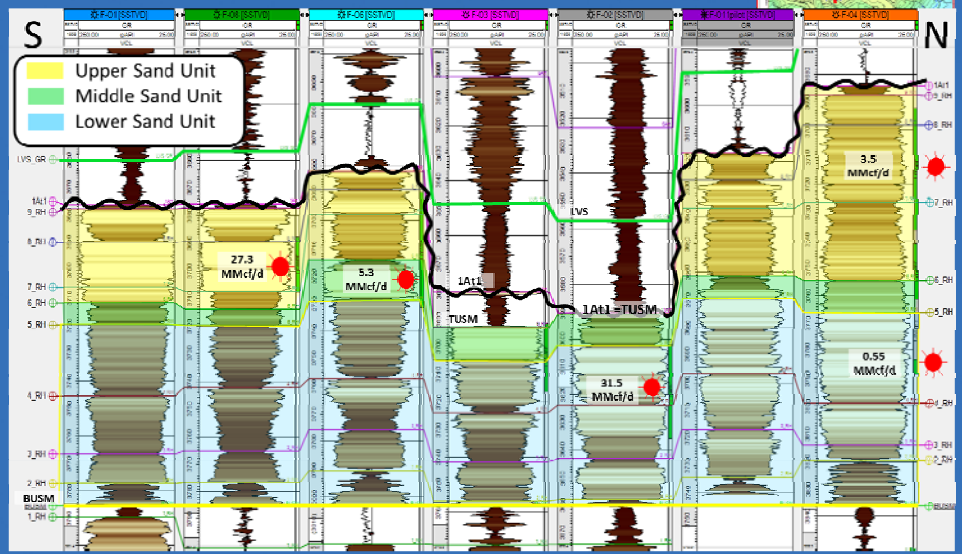
Geological Environment & Structure

- Shallow-marine tidal dune-field at a depth of 3700m
- 3-way dip closure with fault trap
- Compartmentalized reservoir

Reservoir Properties

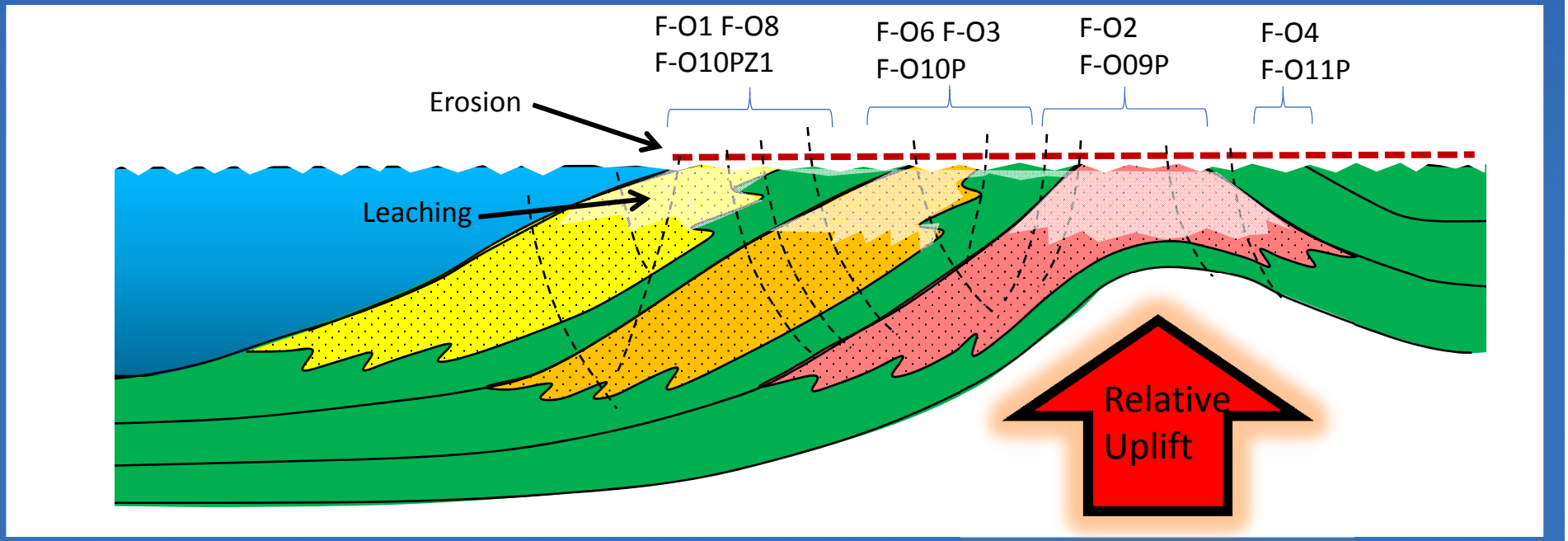
- Reservoir thickness varies between 80-160 m
- Tight gas, heterogeneous
- Porosity range: 2-16% (Ave 9%)
- Permeability range: 0.01-10 mD (Ave1 mD)
- Enhanced poro-perm zone formed by early diagenetic processes exists at the upper part of the reservoir
- HPHT conditions: 7792 psia, 157°C





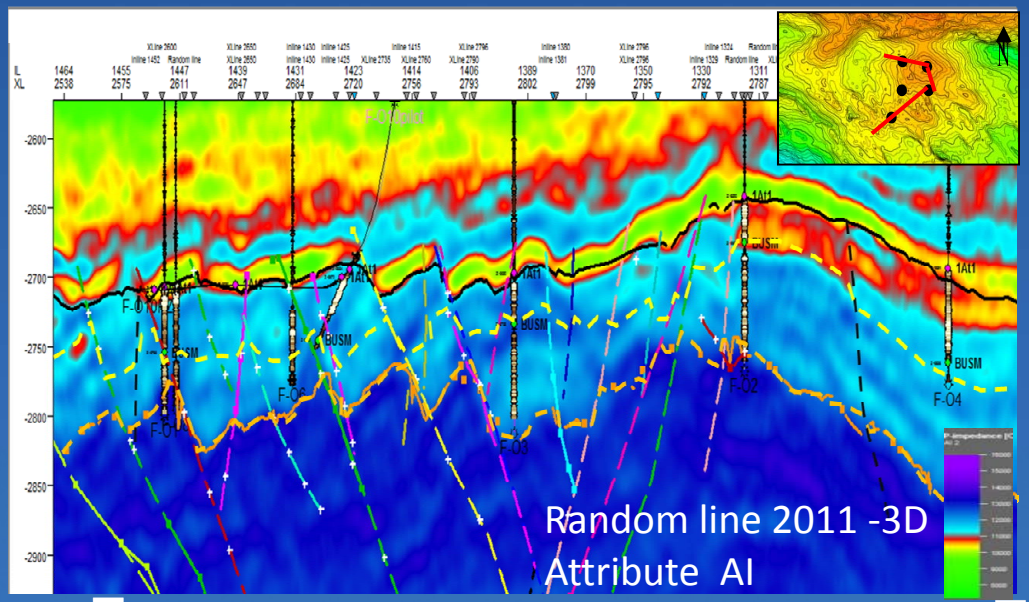
Heterogeneity

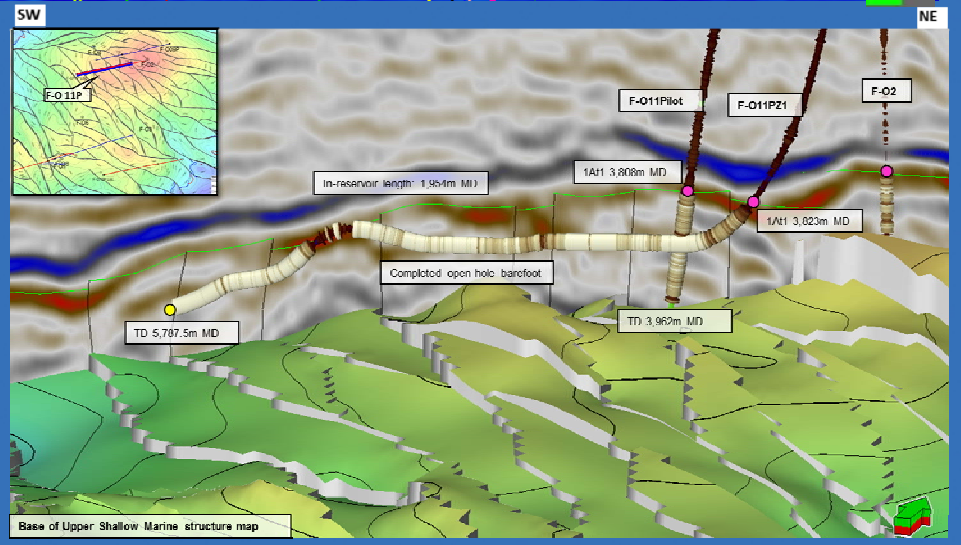
- Enhanced poro-perm zone was targeted within upper 60 m of reservoir formed by diagenetic leaching process



Heterogeneity

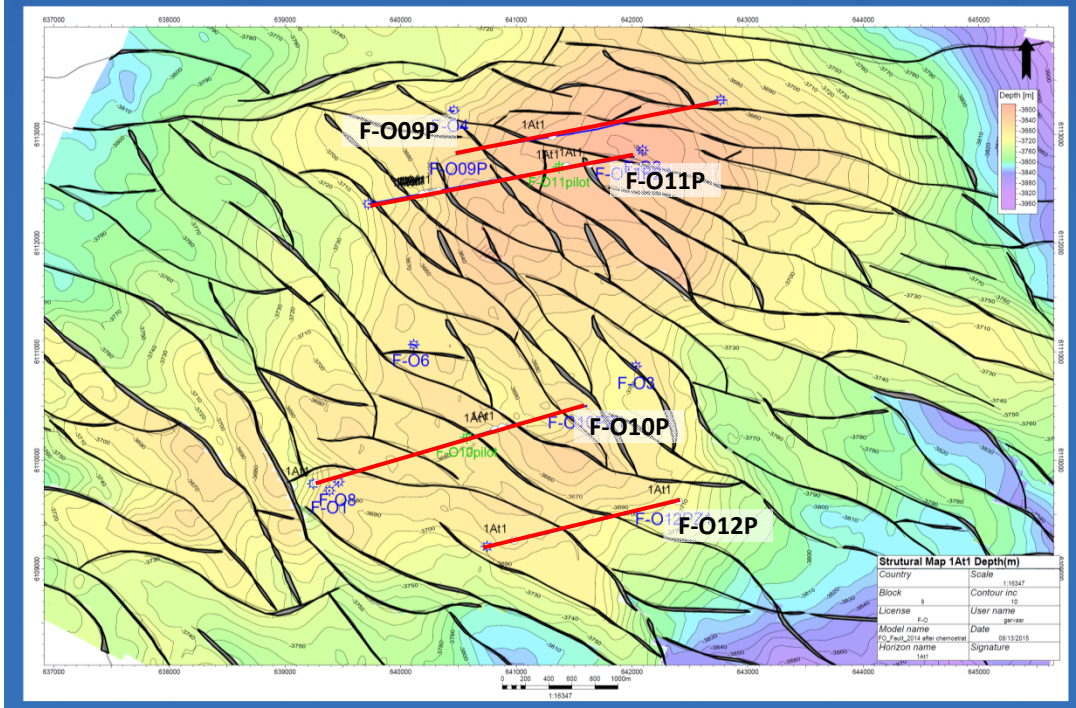
- Seismic attribute data highlighted the broad anomaly over the field but is unable to resolve the enhanced poroperm streaks
- Geosteering technology adopted to react in real time targeting enhanced poroperm zone



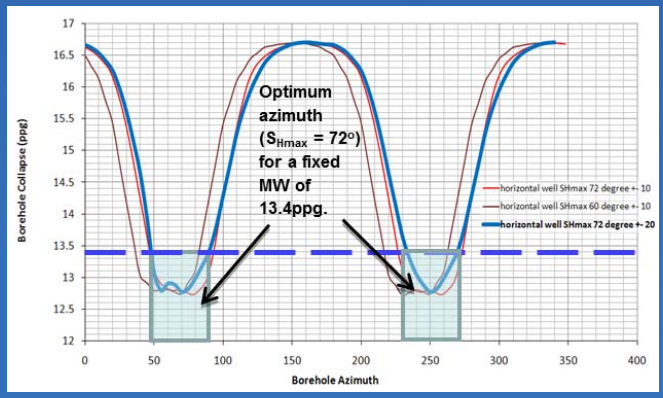


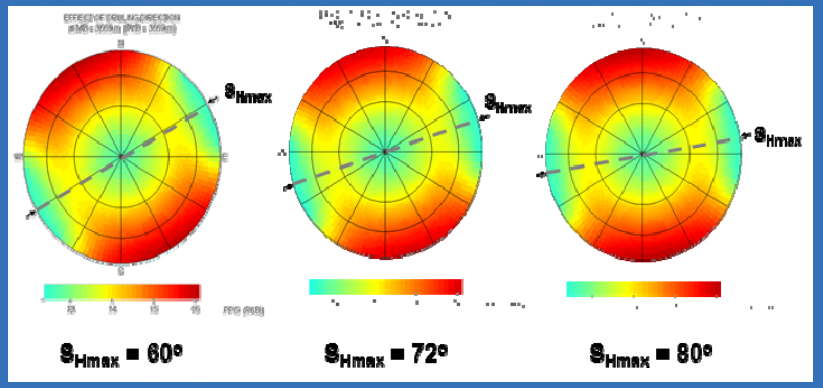
Highly Faulted & Compartmentalized

- Long reach horizontal wells to access multiple fault blocks
  - Horizontal section between 1400-2000 m
  - Geomechanics study guided the optimum drilling direction using lowest mud weight



Top Structure Map (Depth)





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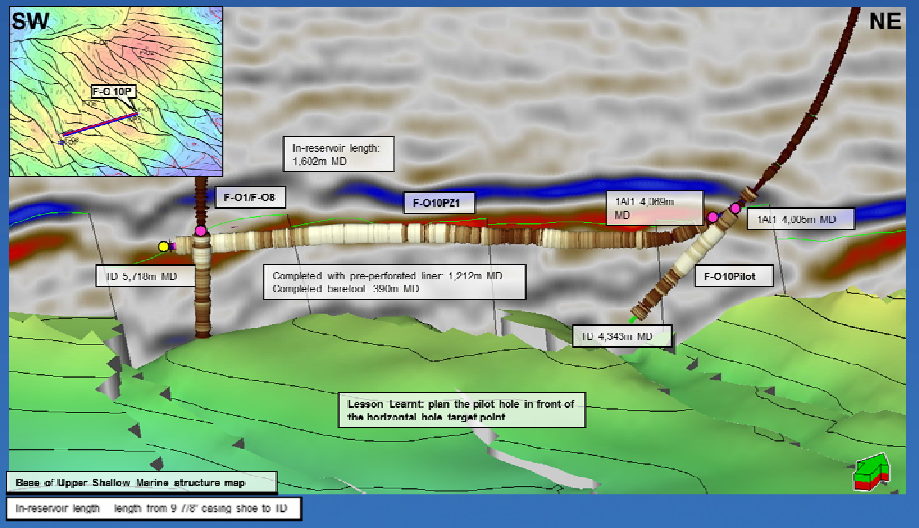
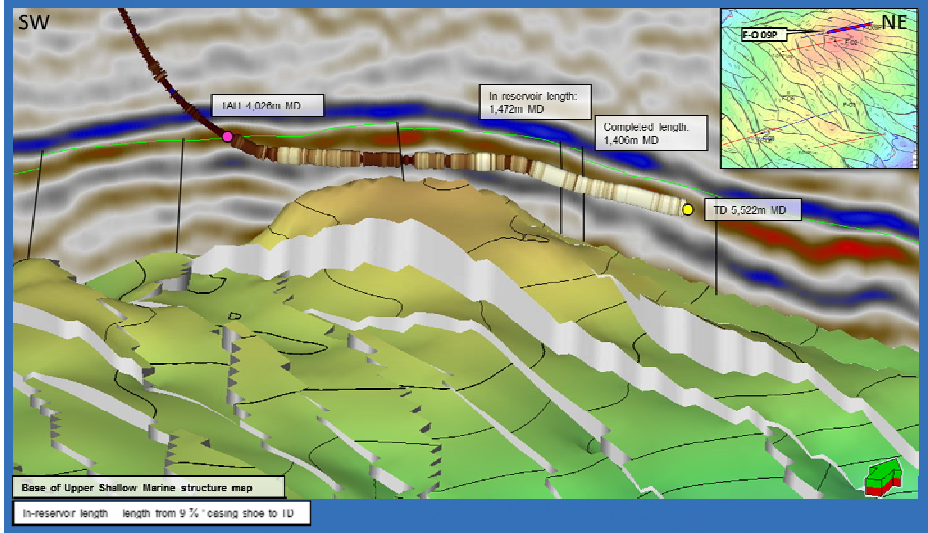
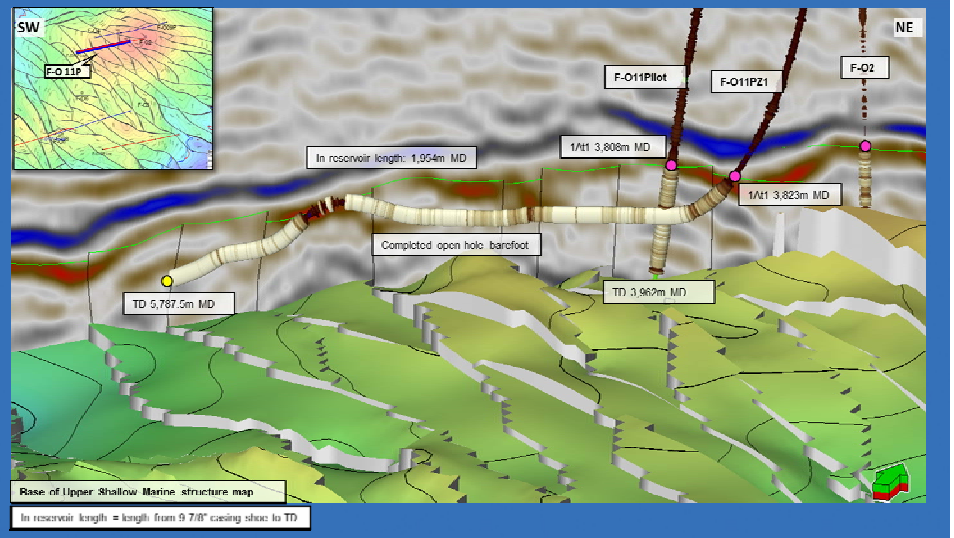
Tight Reservoir

- Different completion applied to each producer
  - With the aim of improving flowrate







Formation Damage, HPHT & Operational Impact on NPT

- Different muds used during campaign
  - Oil based mud initially used
    - Change due to suspected formation damage
  - Potassium Formate
    - resulted in extensive clean-up due to solids
- High Temperature tools
  - Still had high NPT caused by tool failure
- Isolation valves that were required to control the high reservoir pressure failed on two occasions resulted in extended NPT
- Other cause of NPT - multiple episodes of rig operational issues

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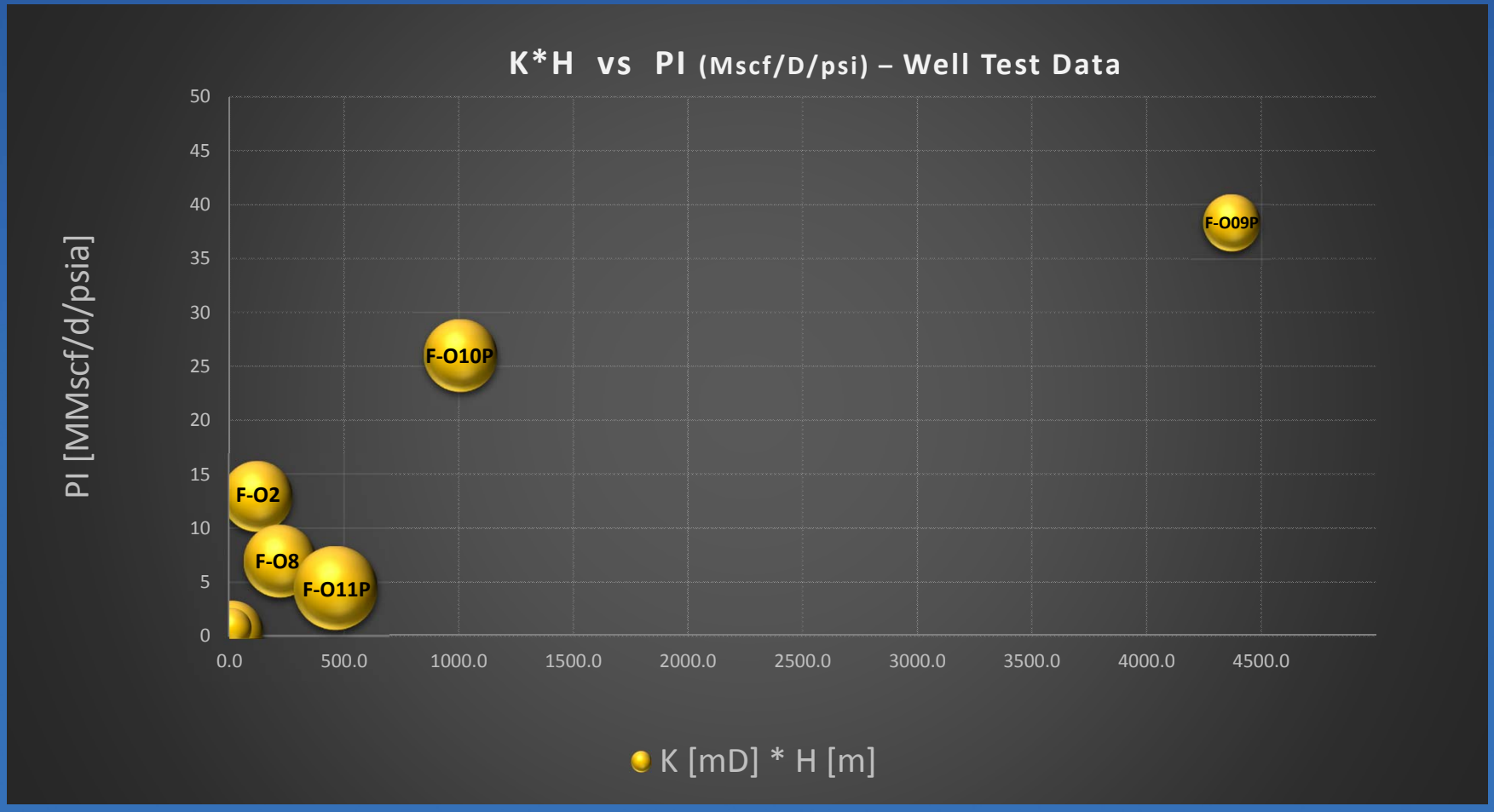
Well Performance



Conclusions

With all the studies and operational considerations taken into account, the production results were expected to be better

- Key success factor: Improve deliverability timeously & economically
  - Intersect high poro-perm streaks
    - Unresolvable by seismic
    - Active geosteering assists but does not guarantee intersection of good facies throughout borehole
  - Compartmentalization
    - Vertical barriers are less relevant than originally thought.
    - Production over time is improving – accessing volume from larger drainage area than initially thought
    - However, not fast enough to be economically convincing in wells with poor facies
    - Stratigraphic boundaries become relevant (horizontal barriers)

Conclusions

What can we do to improve deliverability?

- Investigate other technologies?
  - We exhausted the potential of current seismic data
  - Use of below-bit resistivity tools (to resolve reservoir presence before intersection)

- Multiple completion strategies applied
  - Test the economic viability of stimulation
  - Test alternative well types

- Improving deliverability of this field is key to unlocking hydrocarbon potential of similar fields in the region (Over 1Tscf.)