Unlocking the Remaining Potential of Najmah-Sargelu: Play-Based Exploration in Kuwait*

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Abstract

Middle to Upper Jurassic Sargelu and Najmah reservoirs have been one of the main Jurassic producers in Kuwait over last few decades. With exploration focus shifting to new frontiers away from the large structural traps, play-based exploration is employed to open up new vistas to replicate the exploration successes in less explored western onland and offshore. The play-based exploration involves integrated interpretation of diverse datasets at the regional scale, documenting the presence or absence of each of the play chance factors (charge, reservoir, trap and seal) for each well that has penetrated the play and preparation of common risk segment maps for each of the play elements. The multiplication of the chance factors for play elements gives composite common risk segment map, which provides a synoptic view of the prospective trends. The Najmah-Sargelu section is characterized by a complex lithological suite of interbedded organic rich argillaceous limestone and tight cleaner carbonate reservoirs. The overlying Gotnia Evaporite as top seal and underlying Dharuma tight shaly limestone as base seal define the stratigraphic extent of the Najmah-Sargelu play. Najmah Formation itself is an excellent source rock with average present-day organic richness of 7% in onland Kuwait. It is in oil to wet gas maturity window. The primary reservoirs are Najmah Limestone, Najmah Organic Rich Limestone and Sargelu Limestone. The play is present over the entire country and is characterized by very high historical well success ratio, prospect success ratio and play chance. The play carries very low risks on presence and effectiveness of trap, seal and charge and consequently it is heavily dependent on reservoir presence and effectiveness. Gross depositional environment does not change significantly across the play and the presence/absence of natural fractures is the dominant control on reservoir effectiveness. Seismic based curvature and discontinuity maps appear to be good predictor of natural fractures. Six play segments are mapped based on hydrocarbon phase and curvature. Play segments in eastern and western parts of onland Kuwait have proven play chance and best prospect success rates in view of possibility of encountering maximum fractures, which enhance the flow characteristics. Play segments in the southwestern Kuwait and offshore are envisaged to have relatively moderate chance of success due to moderate deformation resulting in relatively less fracturing.

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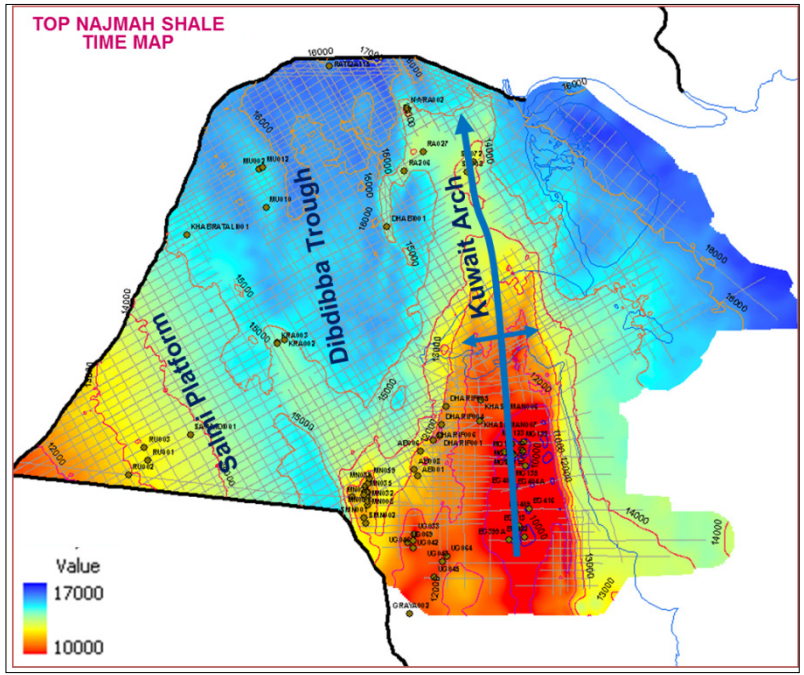
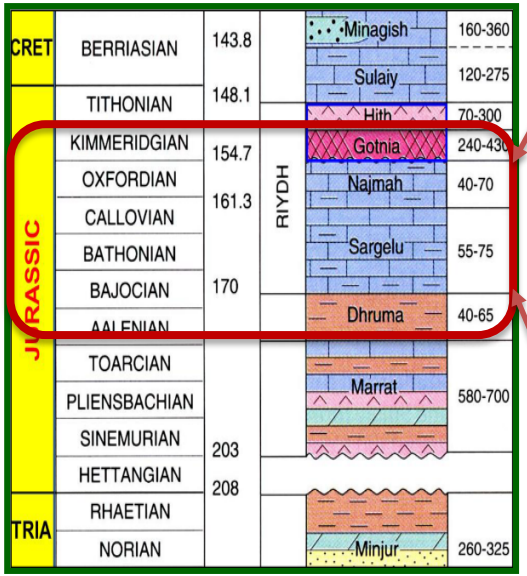
A Subsidiary of Kuwait Petroleum Corporation

Presentation Outline

- Introduction
- Methodology
- Input Data
- Challenges and Constraints
- Play Assessment
- Conclusions

Introduction



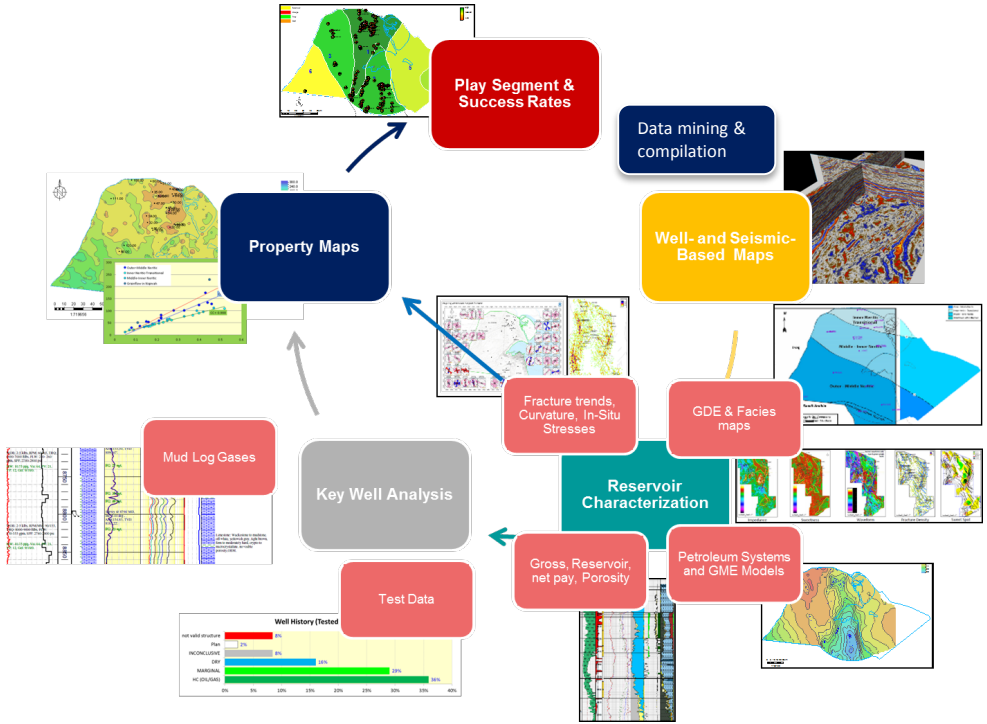


- **Reservoirs:**
- **Upper Najmah Shale (Base Gotnia)**
- **Upper Najmah Limestone**
- **Middle Najmah Shale**
- **Middle Najmah Limestone**
- **Lower Najmah Shale**
- **Lower Najmah Limestone**

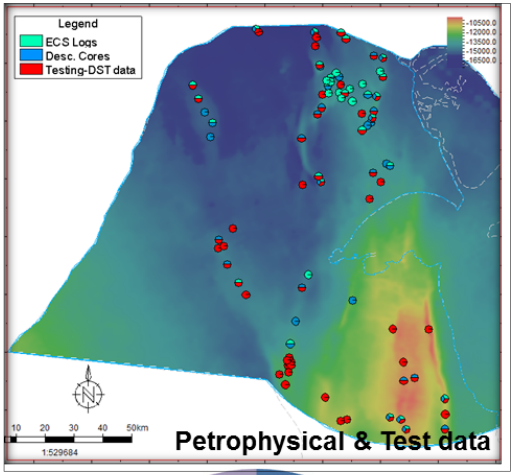
- **Upper Sargelu**
- **Lower Sargelu**

Objective: Analyze country-wide exploration potential of Najmah and Sargelu formations and prioritization of areas for focused exploration

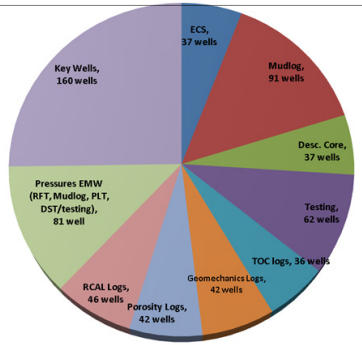
Methodology / Workflow of Play Fairway Assessment

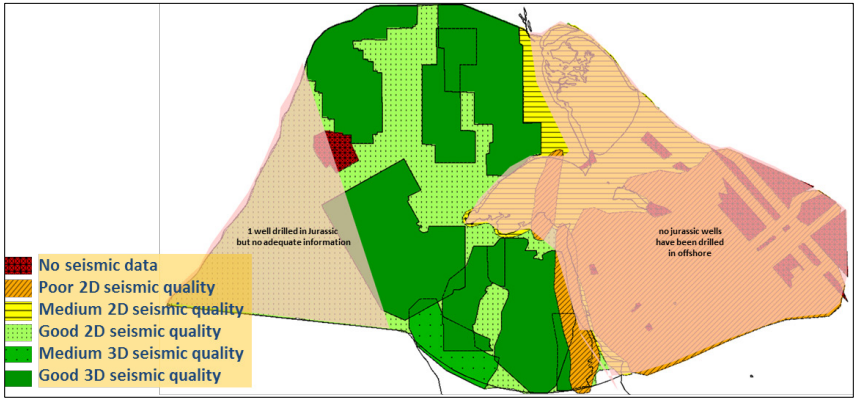


Input Data, Challenges & Constraints



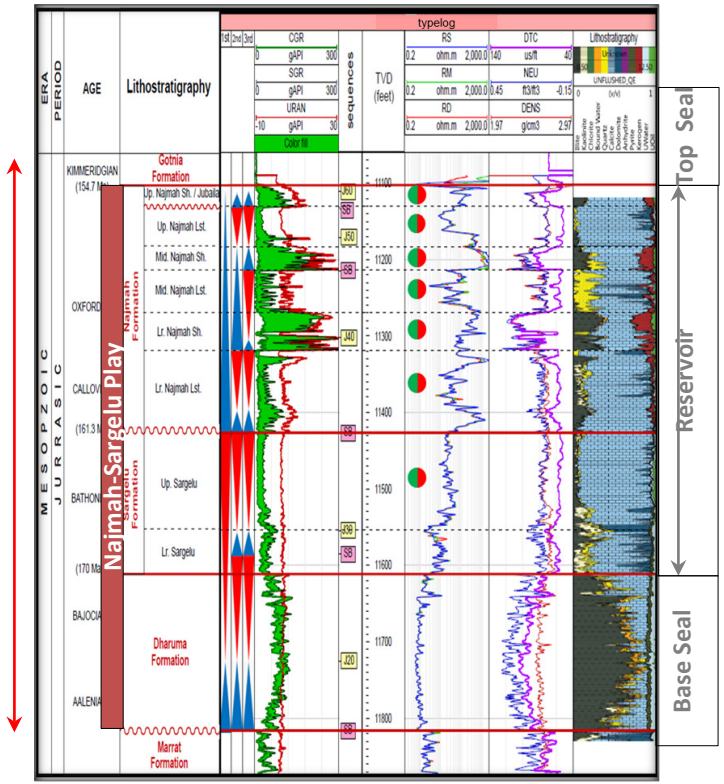
- 2D Seismic: 15000 LKM
- 3 D Seismic: 10 Surveys
- Key Wells: 162 wells
- ECS: 37 wells
- Test Data: 62 wells
- API Gravity: 42 wells
- GOR data : 30 wells
- Mud Logs : 91 wells
- RCAL: 46 wells
- Petrophysics: 42 wells
- Core : 37 wells
- *No Jurassic wells have been penetrated in offshore*





- 2D and 3D seismic data available; quality is not consistent.
- No well data in western Onland, Bubiyan, Kuwait Bay and Open Offshore

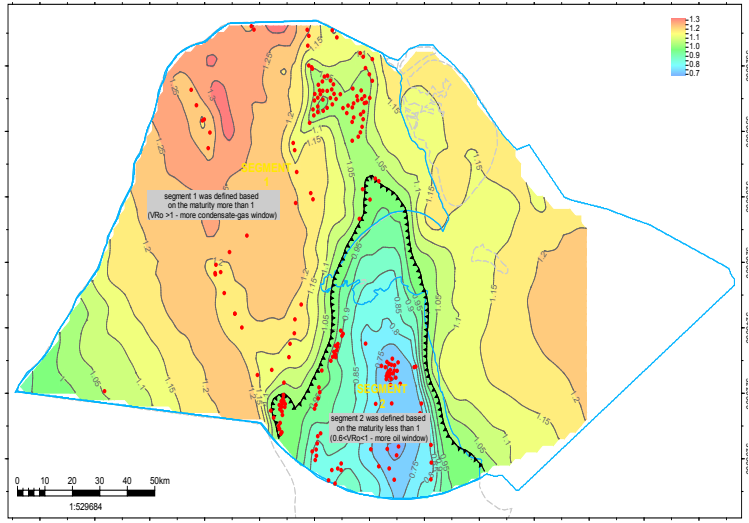
Najmah-Sargelu Play



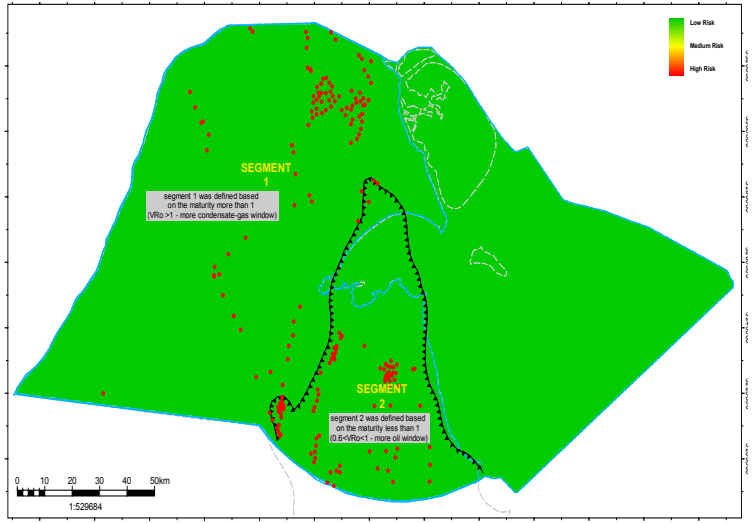
- Stratigraphically defined by Gotnia Top seal and Dharuma base seal.
- Charged by Najmah
- Primary reservoirs are Upper Sargelu Lst, Najmah Shale and Limestones.
- Play fairway covers the entire country.

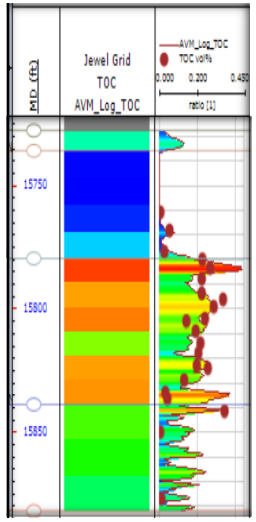
Charge CRS (Common Risk Segment)

Charge (VRo map)



Charge CRS

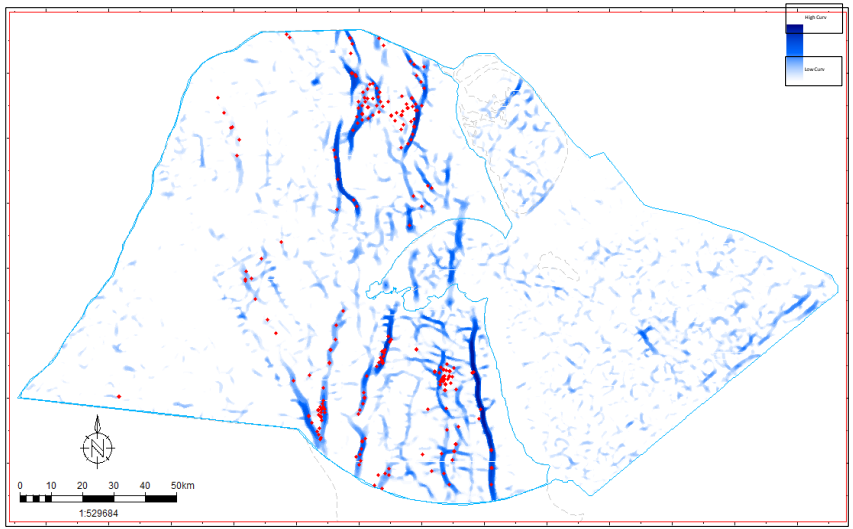




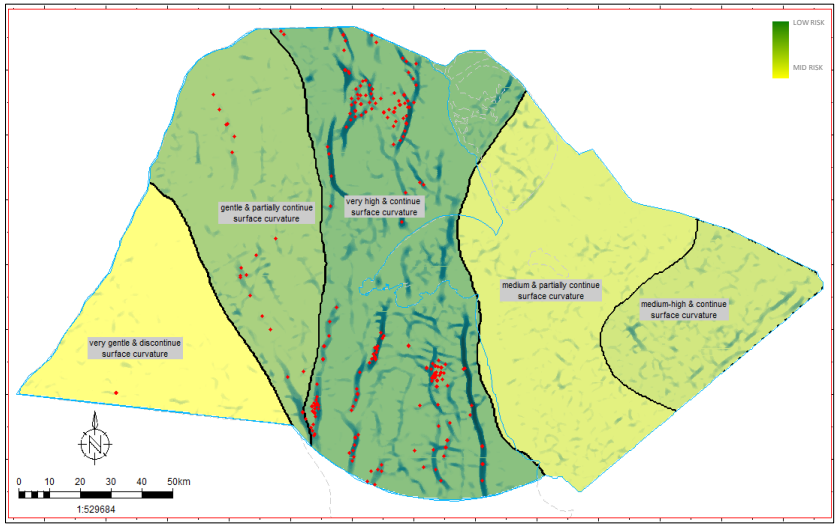
VRo maps shows that 2 segment can be identified;
VRo above 1 (more condensate – gas window)
0.6 < VRo < 1 (more oil window)

Reservoir CRS (Common Risk Segment)

Reservoir (Max Curvature map)

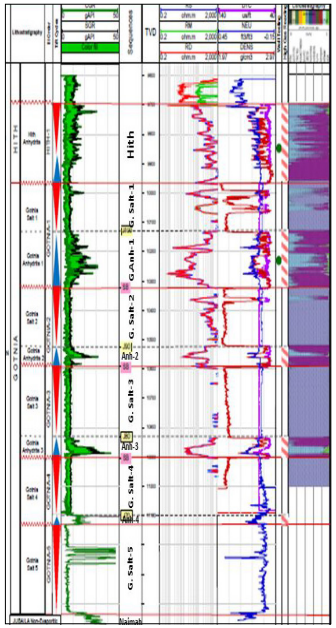


Reservoir CRS

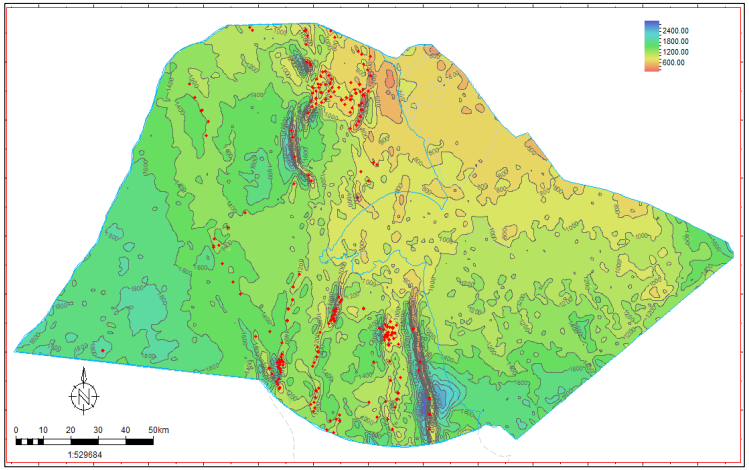


Max curvature shows good agreement with wells that produce HC and gives entire picture of Kuwait

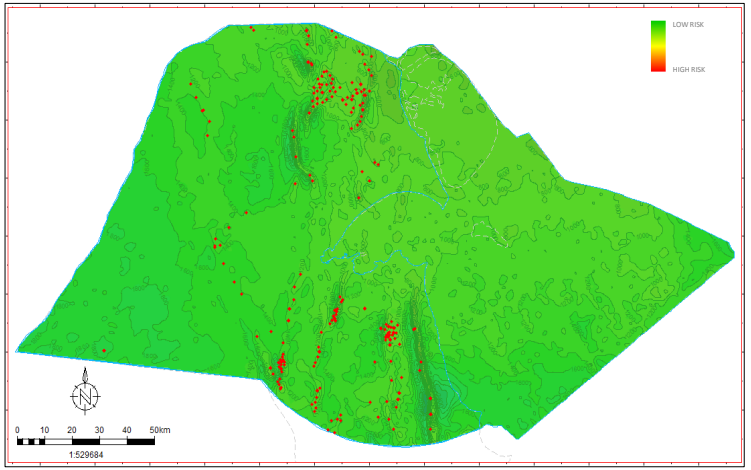
Seal CRS (Common Risk Segment)



Seal (Hith-Gotnia thickness map)



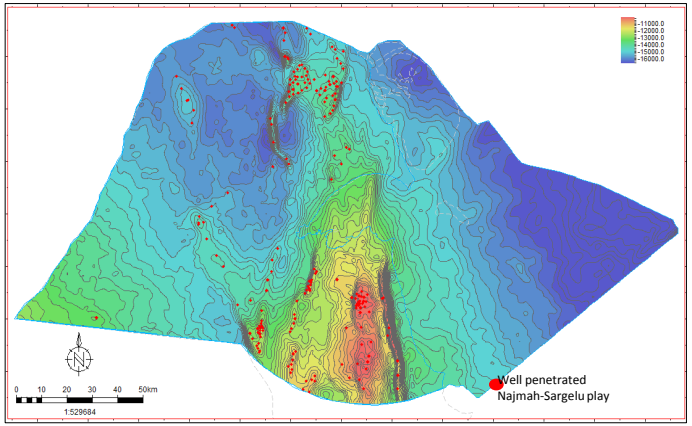
Seal CRS



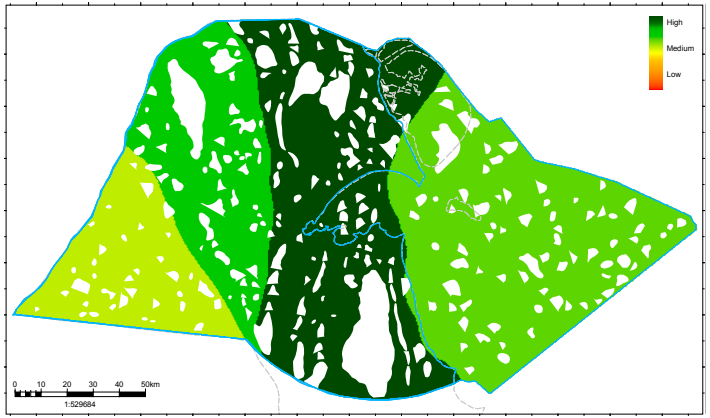
Gotnia and Hith fm. composed of thick interbedded salt-anhydrite across Kuwait with some thin streaks/intercalations of limestone

Trap CRS (Common Risk Segment)

Trap (Najmah-Sargelu play Structure map)

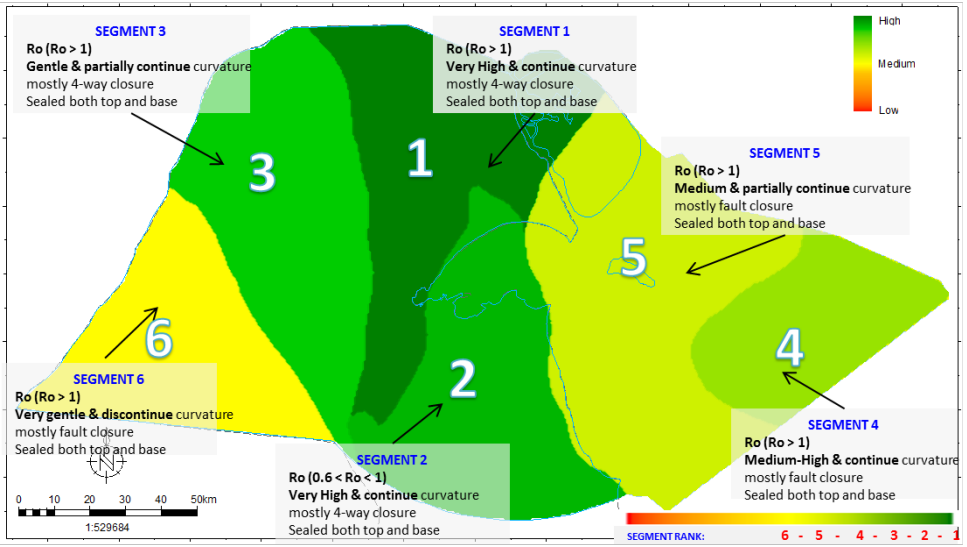


Trap CRS

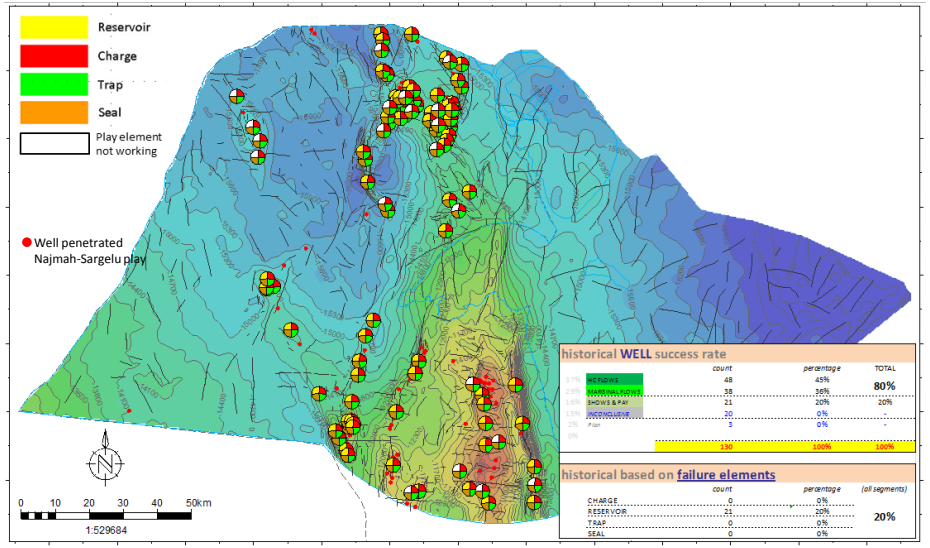


Najmah-Sargelu average porosity is around 5% and relatively uniform across the region; from drilled wells shows HC occurrences whenever it was drilled; especially in the area of high structure and/or faulted. Therefore; trap CRS consider as low risk.

Najmah-Sargelu CCRS (Composite Common Risk Segment)



Najmah-Sargelu Key Well Analysis

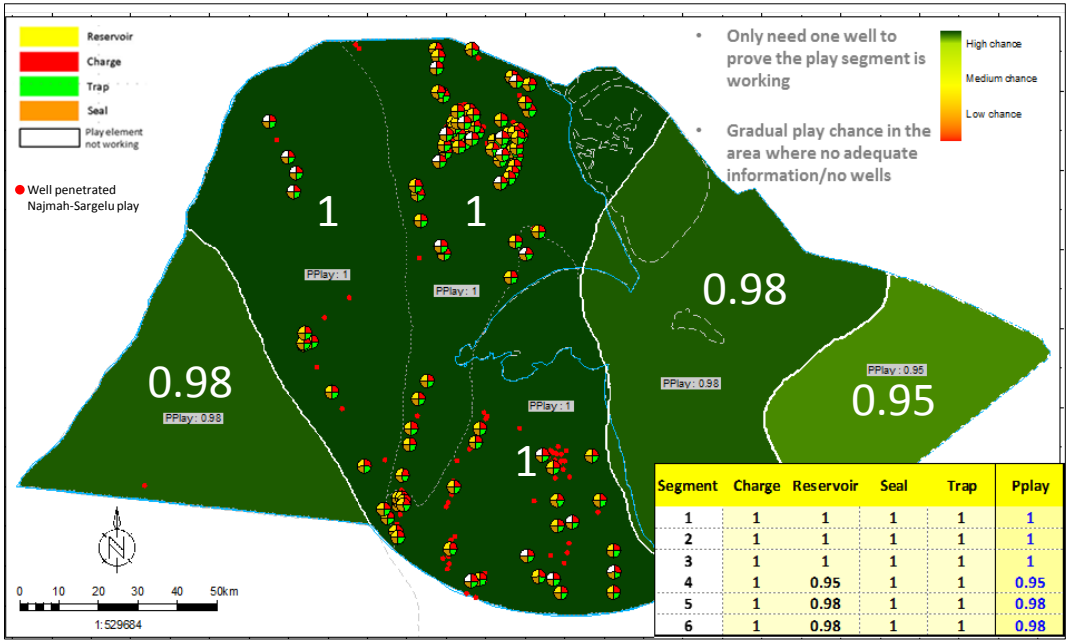


From the curvature we get 5 segments & 1 extra segment

From the charge.

The 4 play elements for the wells which penetrated NJ/SR play are working except areas with low curvature & fracture.

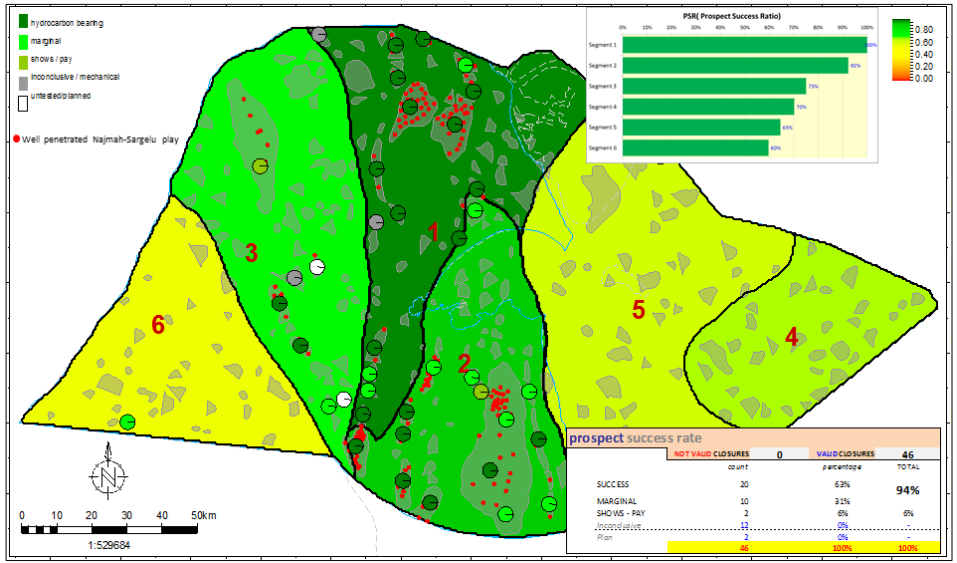
Play Chance: Najmah-Sargelu



Segment	Charge	Reservoir	Seal	Trap	Pplay
1	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1
4	1	0.95	1	1	0.95
5	1	0.98	1	1	0.98
6	1	0.98	1	1	0.98

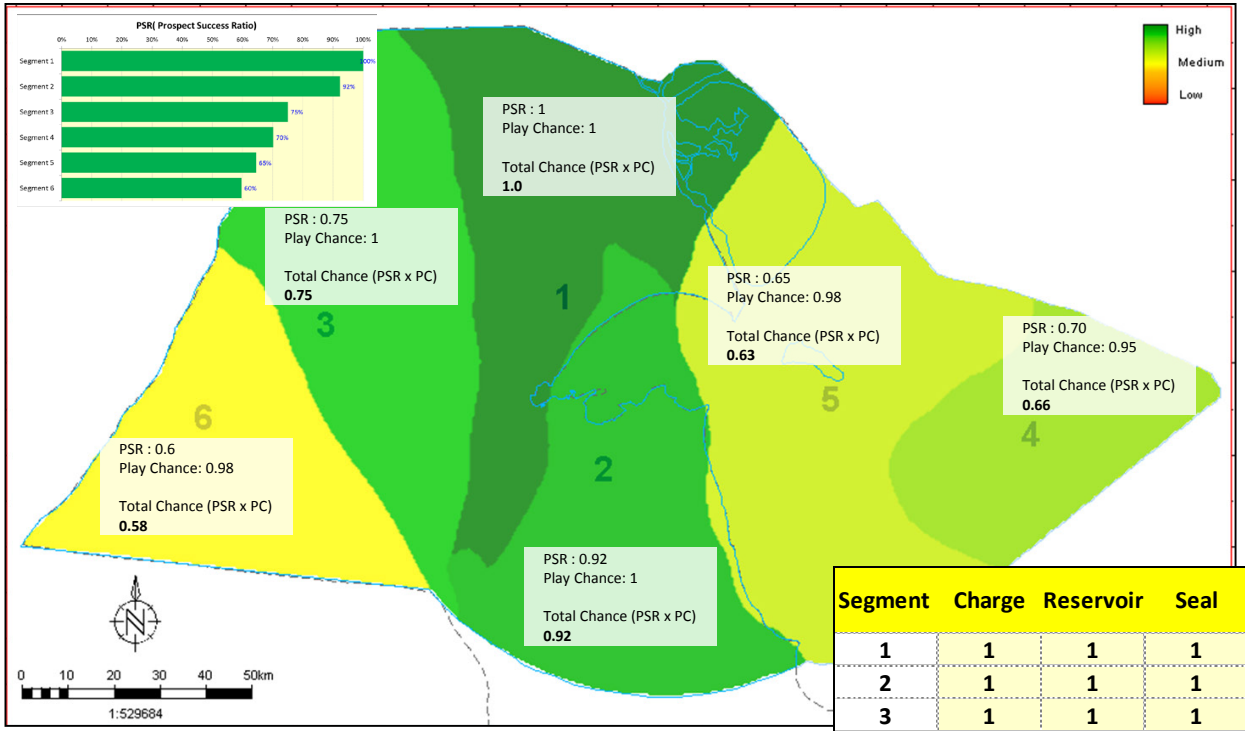
It's a probability in the play segment of at least one geological success. If there is 1 HC bearing well within a segment it is 1.0.

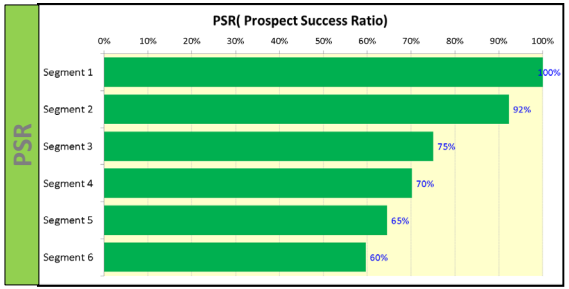
Prospect Success Ratio (PSR): Najmah-Sargelu



It's a ratio where at least 1 well within prospect produces flowable HC.

Total Chance: Najmah-Sargelu play





Play chance

Segment	Charge	Reservoir	Seal	Trap	Pplay
1	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1
4	1	0.95	1	1	0.95
5	1	0.98	1	1	0.98
6	1	0.98	1	1	0.98

Segment	Charge	Reservoir	Seal	Trap	Pplay	PSR	COS (Total Chance)
1	1	1	1	1	1	1	1
2	1	1	1	1	1	0.92	0.92
3	1	1	1	1	1	0.75	0.75
4	1	0.95	1	1	0.95	0.7	0.665
5	1	0.98	1	1	0.98	0.65	0.637
6	1	0.98	1	1	0.98	0.6	0.588

Conclusion

- Najmah-Sargelu is an established play covering Onland and Offshore Kuwait.
  - Very high play chance (above 90%) and PSR (94%).
- Charge, seal and trap are high chance elements.
- Reservoir presence and effectiveness are the major drivers for play chance.
  - Tight reservoir with porosity in the range of 5% and permeability in nannodarcies.
  - Producibility controlled by natural fractures.
  - Maximum curvature is considered as predictor for natural fractures for reservoir CRS.
- A total of six play segments have been identified; central Kuwait appears to hold high potential.