Un-conventional Miocene Reservoirs (Low Resistivity Pay) Success Story, El-Morgan Field, Gulf of Suez, Egypt.

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Under The Patronage of
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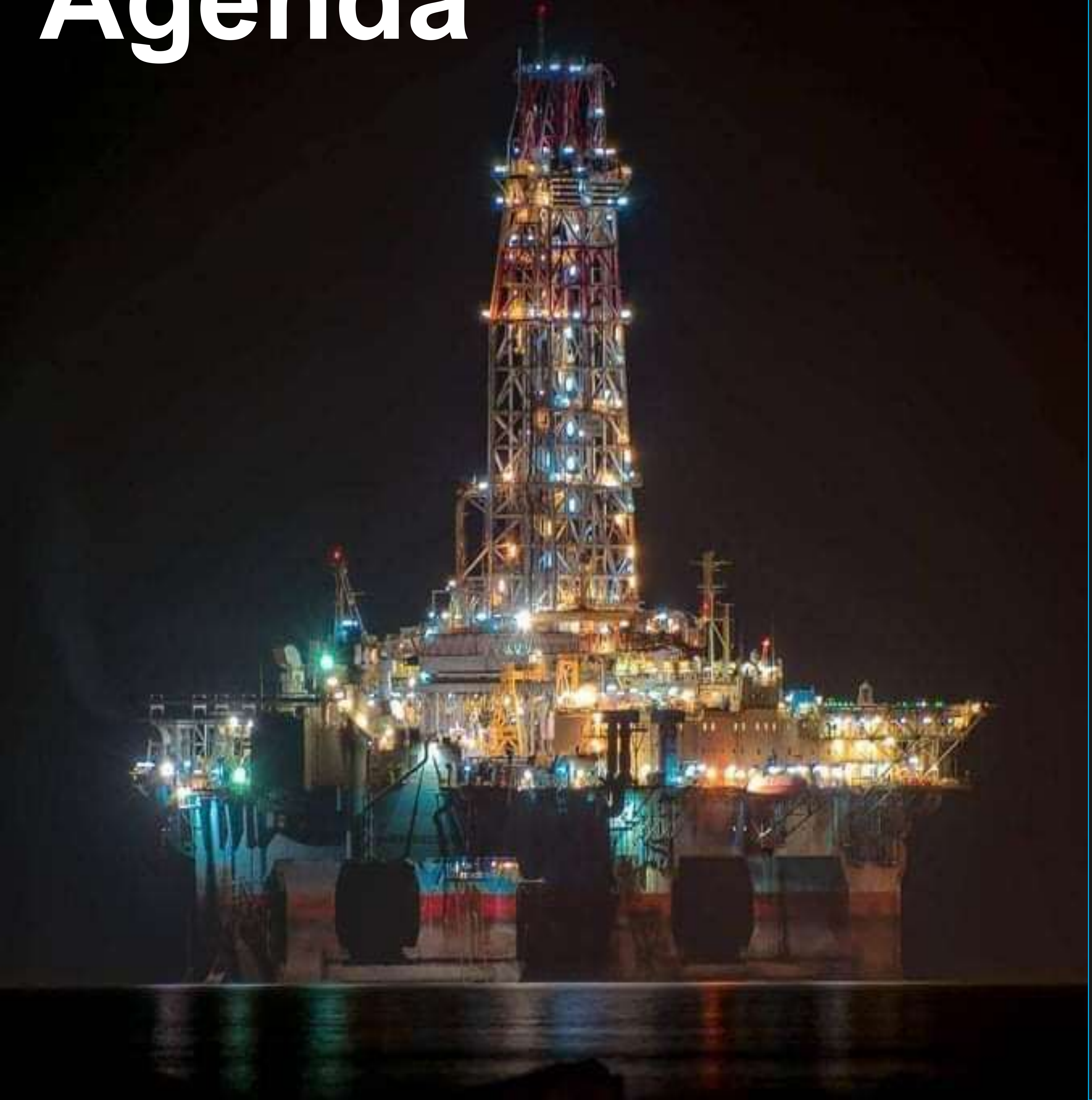
Agenda

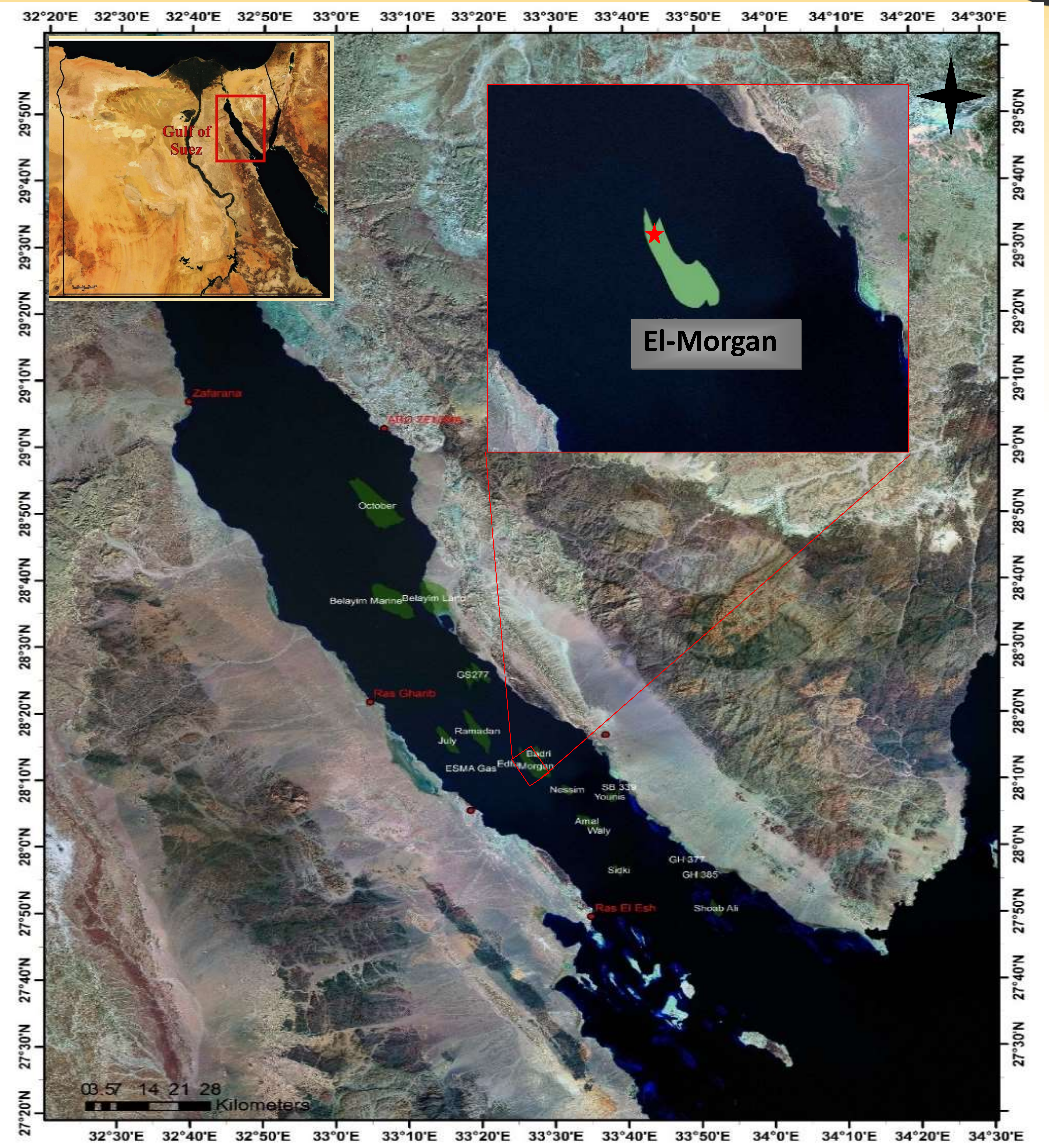


- Introduction
- Geologic setting
- Problem explanation
- Workflow
- Applied techniques
- Summary & Conclusions

Introduction

EL-Morgan Field

- Southern part of the GOS, 13 Km NW of El-Tor.
- Covers area 46 Km2 (Belayim, Kareem & L. Rud).
- Discovered in 1965 and start production in 1967.
- El-Morgan field STOIIP of 2.7 BBO.



- Paper presents successful wells produced from LRP of Miocene clastics, Gulf of Suez.

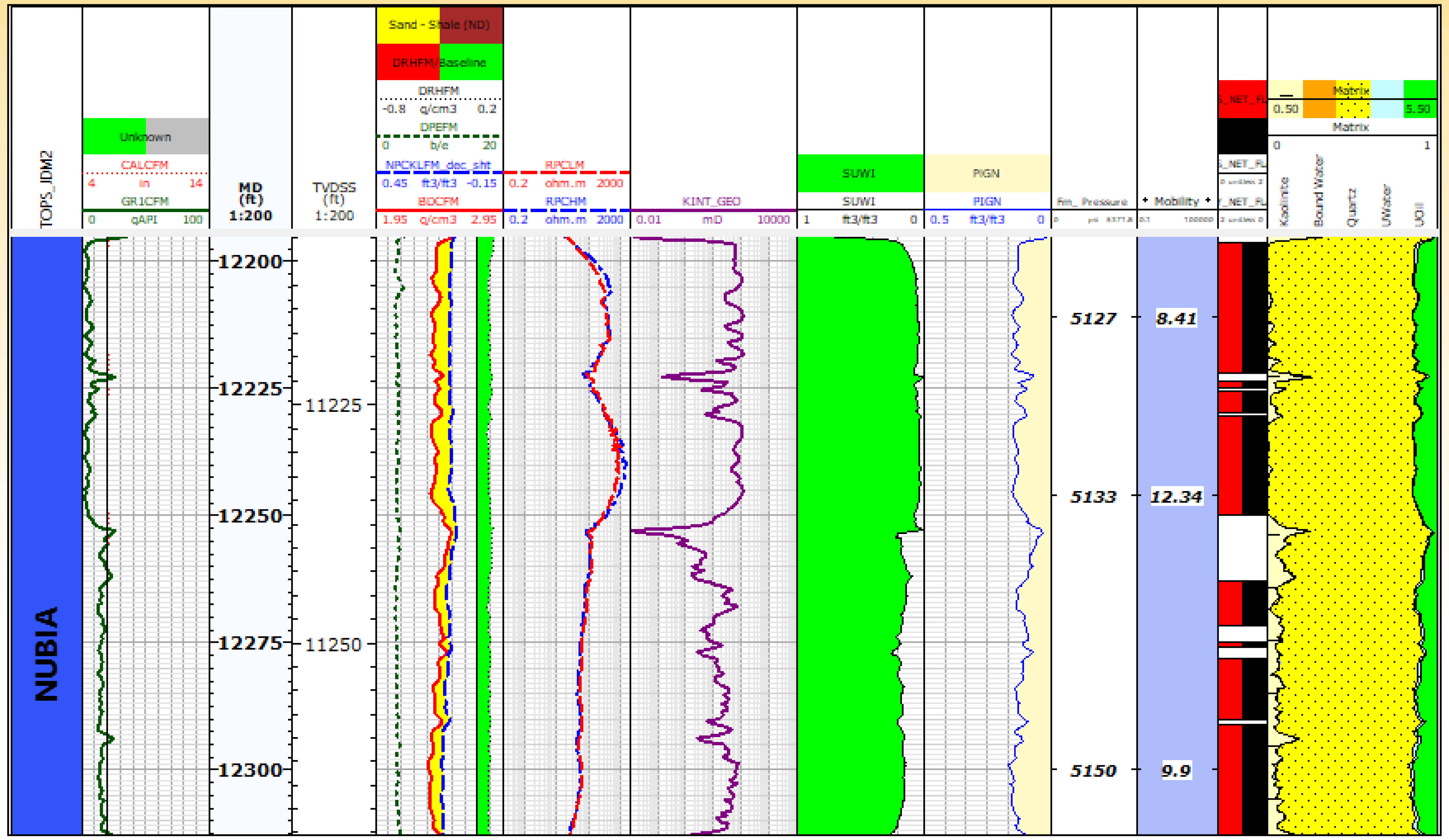
- The traditional petrophysical calculations indicated that they are highly saturated with water.

Introduction

❑ Types of Reservoirs

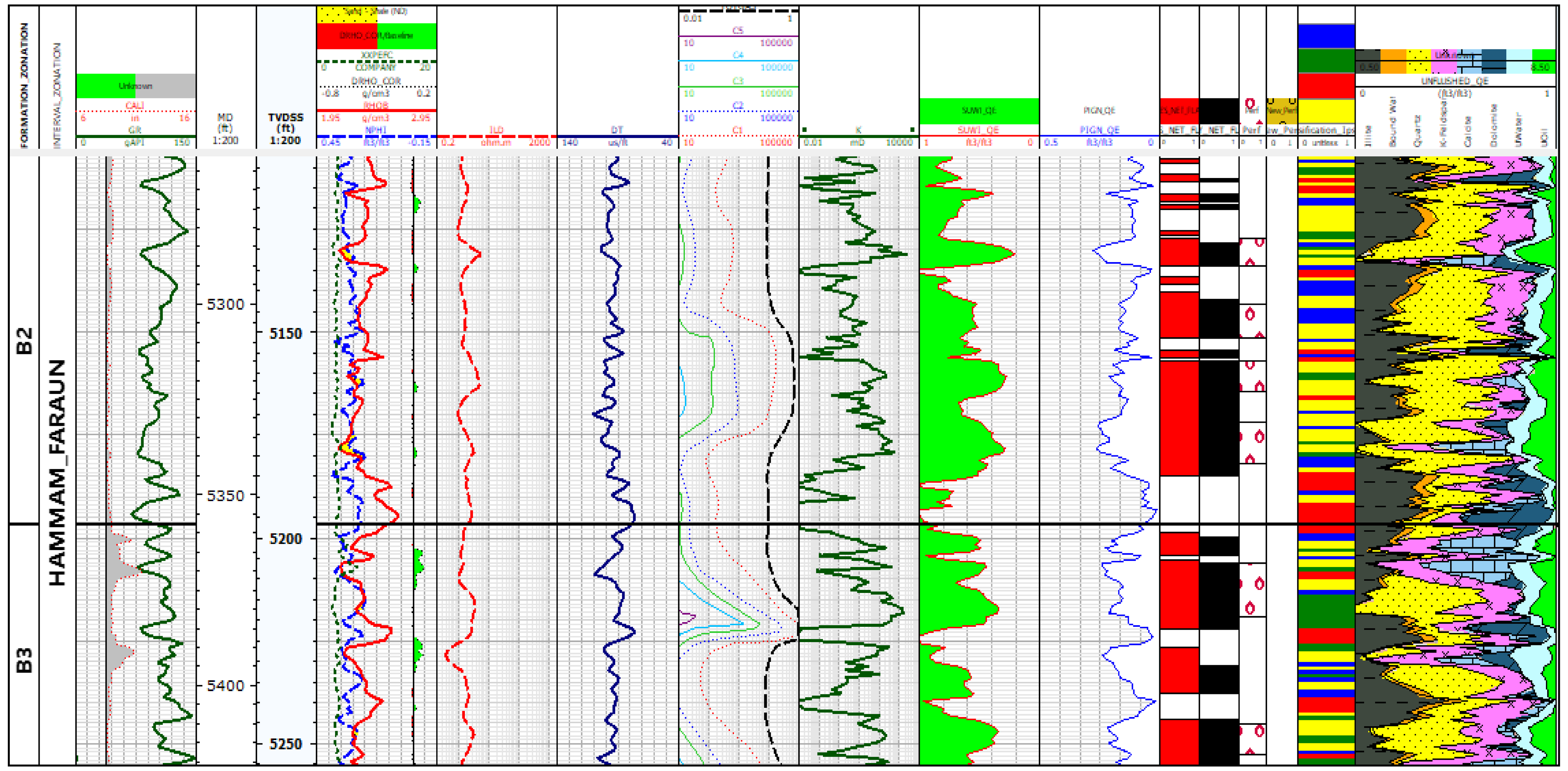
1- Conventional reservoirs:

Reservoir relatively straightforward to develop, they don’t need specialized technologies to unlock their potential. Because they are easier and less expensive to produce (e.g. clean sandstone reservoir).



2- Un-conventional reservoirs:

Reservoirs with low permeability or low electrical resistance. In order to produce, industry uses a stimulation technique like hydraulic fracturing.



Introduction

❑ Definition of Low Resistivity Pay (LRP)

Low resistivity pay is a reservoir which exhibits low electrical resistance (high calculated Sw) and can produce hydrocarbon associated with low water cut (Austin, et al, 1995).

Reasons:

1) Presence of clays and their distribution.
2) Fine grained (silty) sand.
3) Presence of conductive minerals.

Traditional Evaluation:

Traditional petrophysical calculations will reflect high water saturation which will result in errors in STTOIP calculations.

Solution:

Acquire high technology logging tools such as NMR ,ADT , 3 dimensional resistivity (RT scanner), ECS…..etc. In addition to Core/Side-Wall Core.

Geologic setting

❑ Structural Framework of the Gulf of Suez

- **Three major tectonic dip provinces are defined within Gulf of Suez**

➢ Darag Province. (SW Dipping)

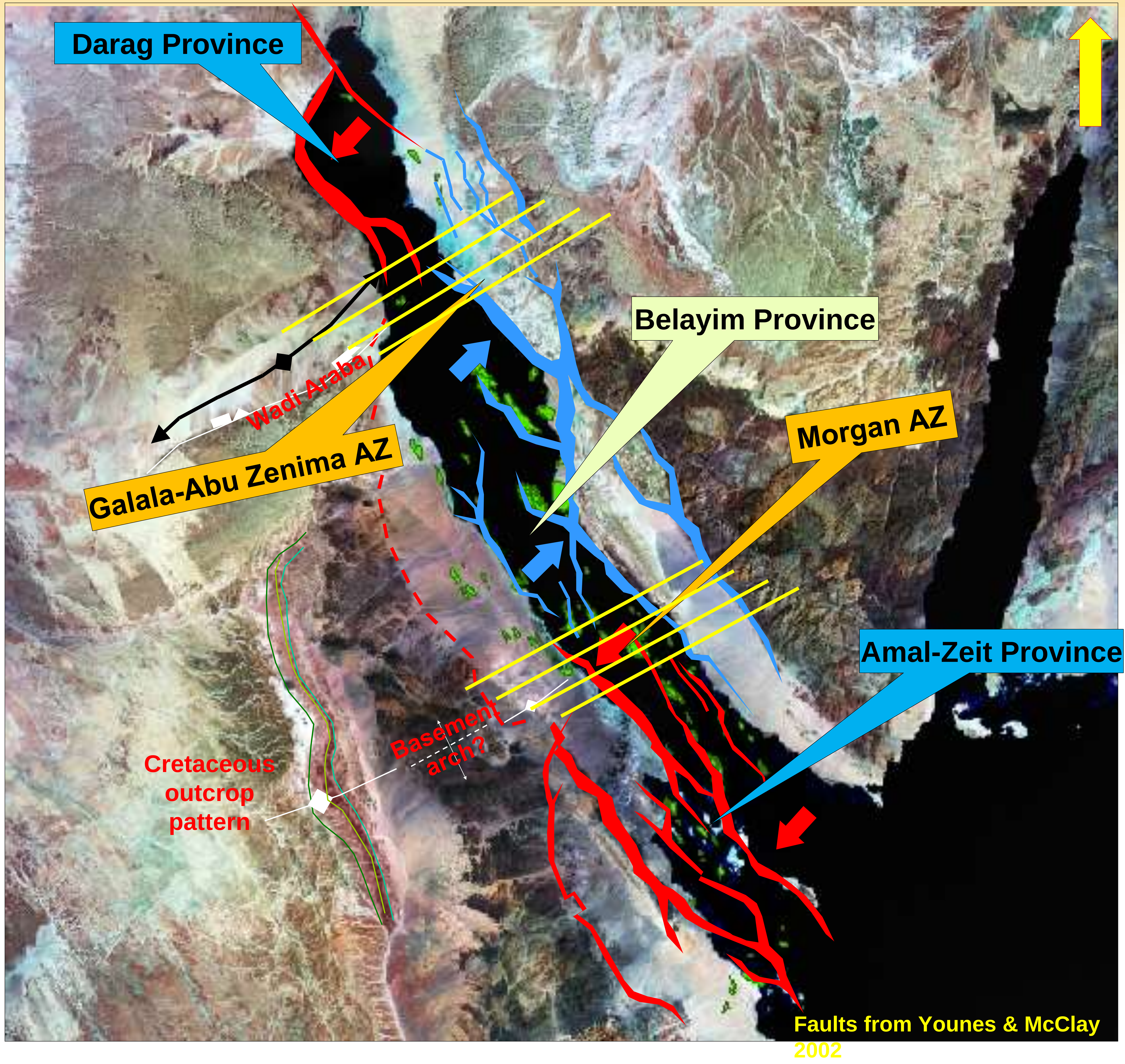
➢ Belayim Province. (NE Dipping)

➢ Amal-Zeit Province. (SW Dipping)

- **These provinces are separated by two Northeasterly trending accommodation zones:**

➢ Galala-Abu Zenima accommodation zone.

➢ Morgan accommodation zone.

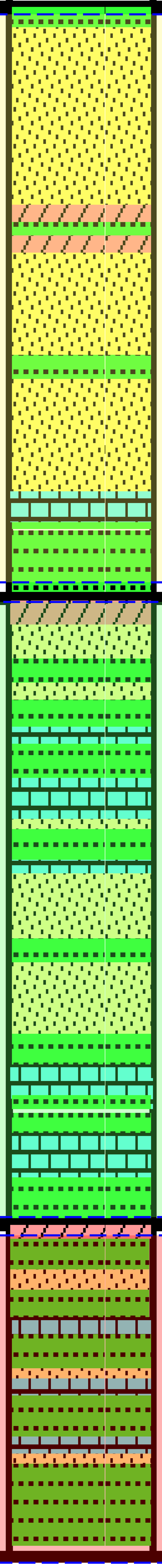


Geologic setting

❑ Stratigraphic Framework of Morgan Field (Miocene)

○ Belayim Formation Stratigraphy

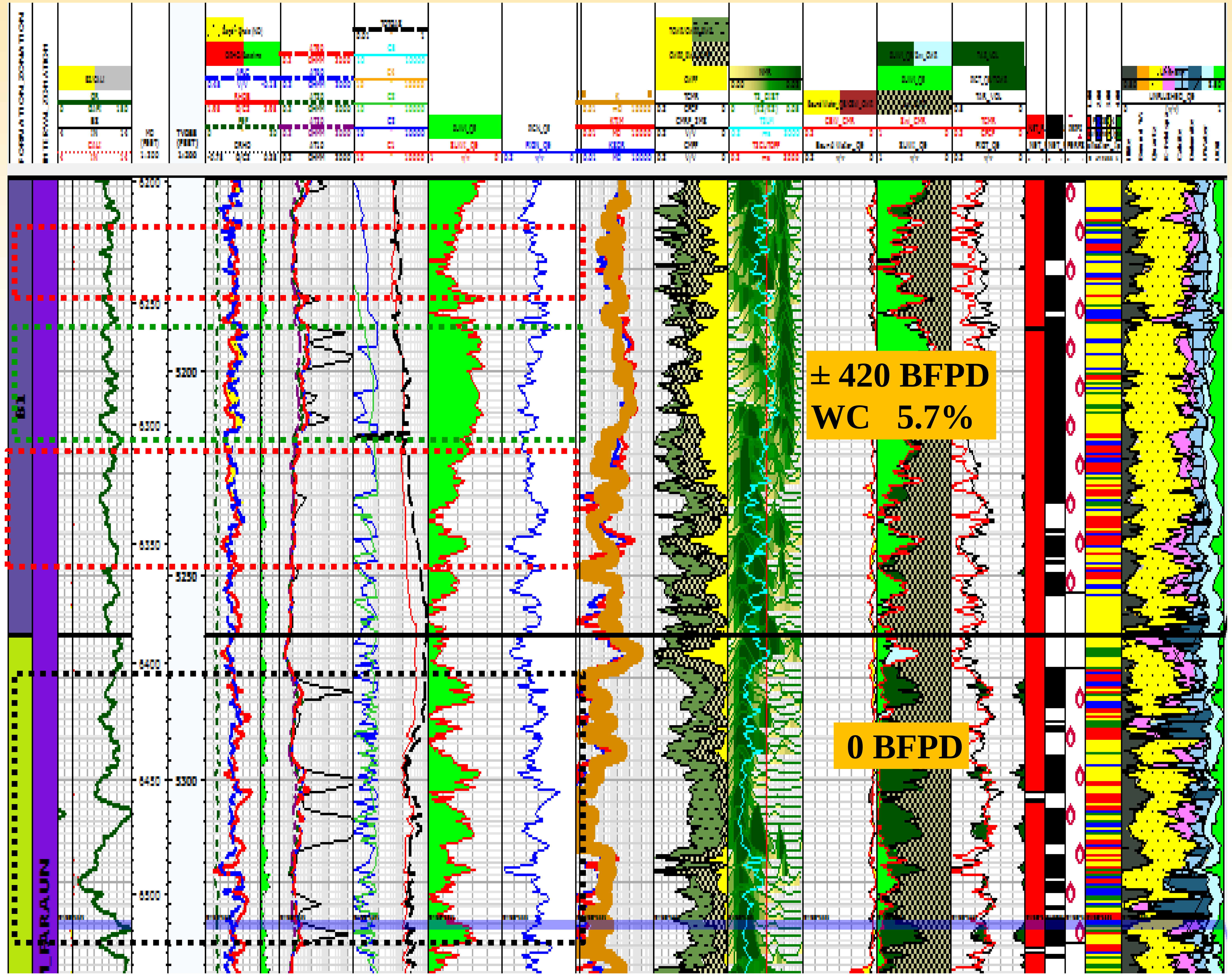
- Baba Member
- Sidri Member
- Feiran Member
- Hammam Faraun Member

Zones	Lithology	Description	Environments
B1		Upper reservoir, good quality and main production zone	Upper fan delta complex
B2		Intermediate reservoir, less quality than B1, separated from the upper reservoir by impermeable shale streak	Lower fan delta complex, separated from one above by marine transgressive phase.
B3		Lower reservoir, Low quality and poorly facies	Distal portion of the fan delta

Problem explanation

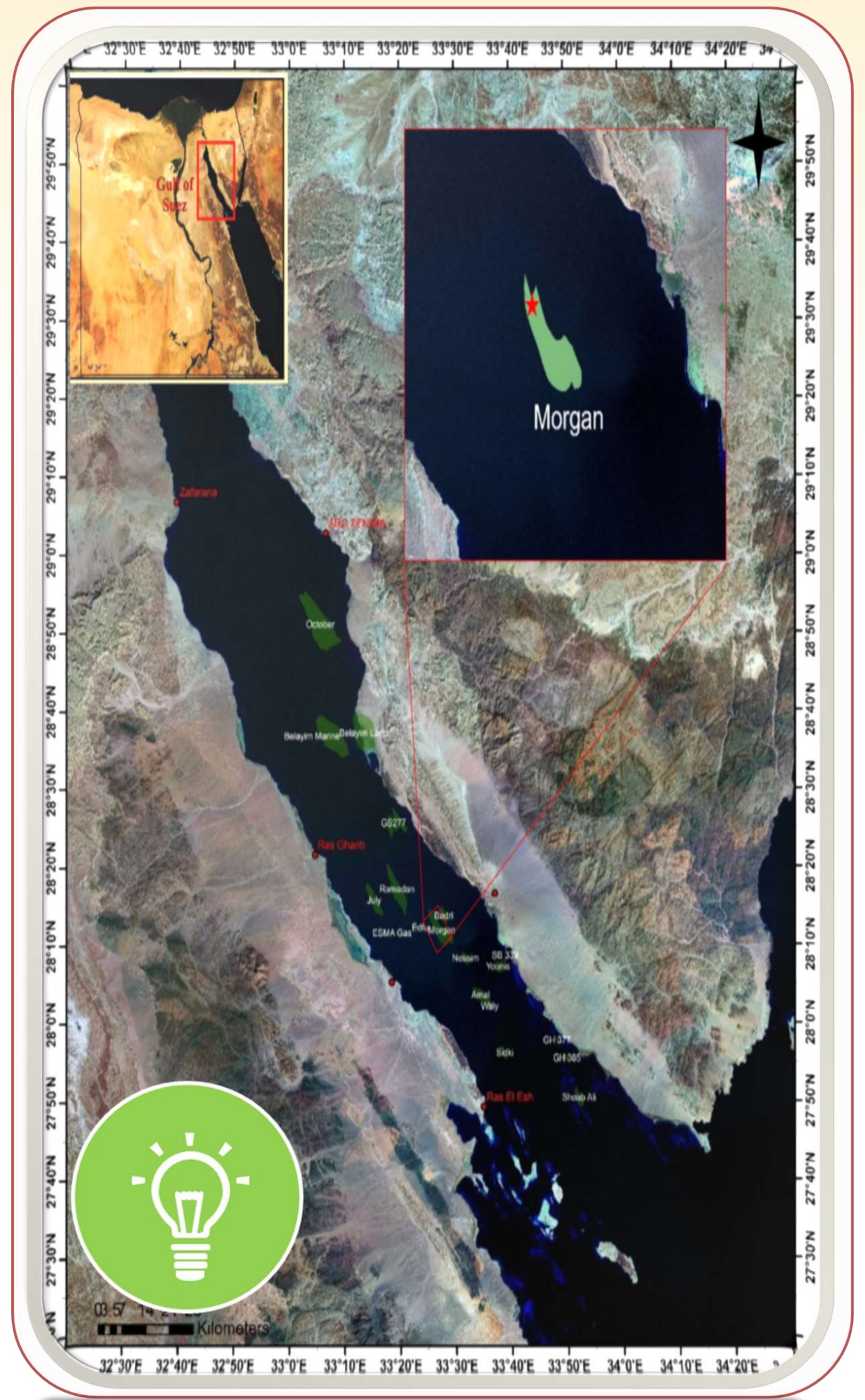
❑ Low resistivity pay challenges

- **In-situ hydrocarbon underestimation**
  - Sw computed > Sw real
- **Bypassed pay**
  - Computed high Sw true but water is not moveable
- **Uncertainty which intervals to perforate and test**
  - Shoot everything? Plug & abandon?



Workflow

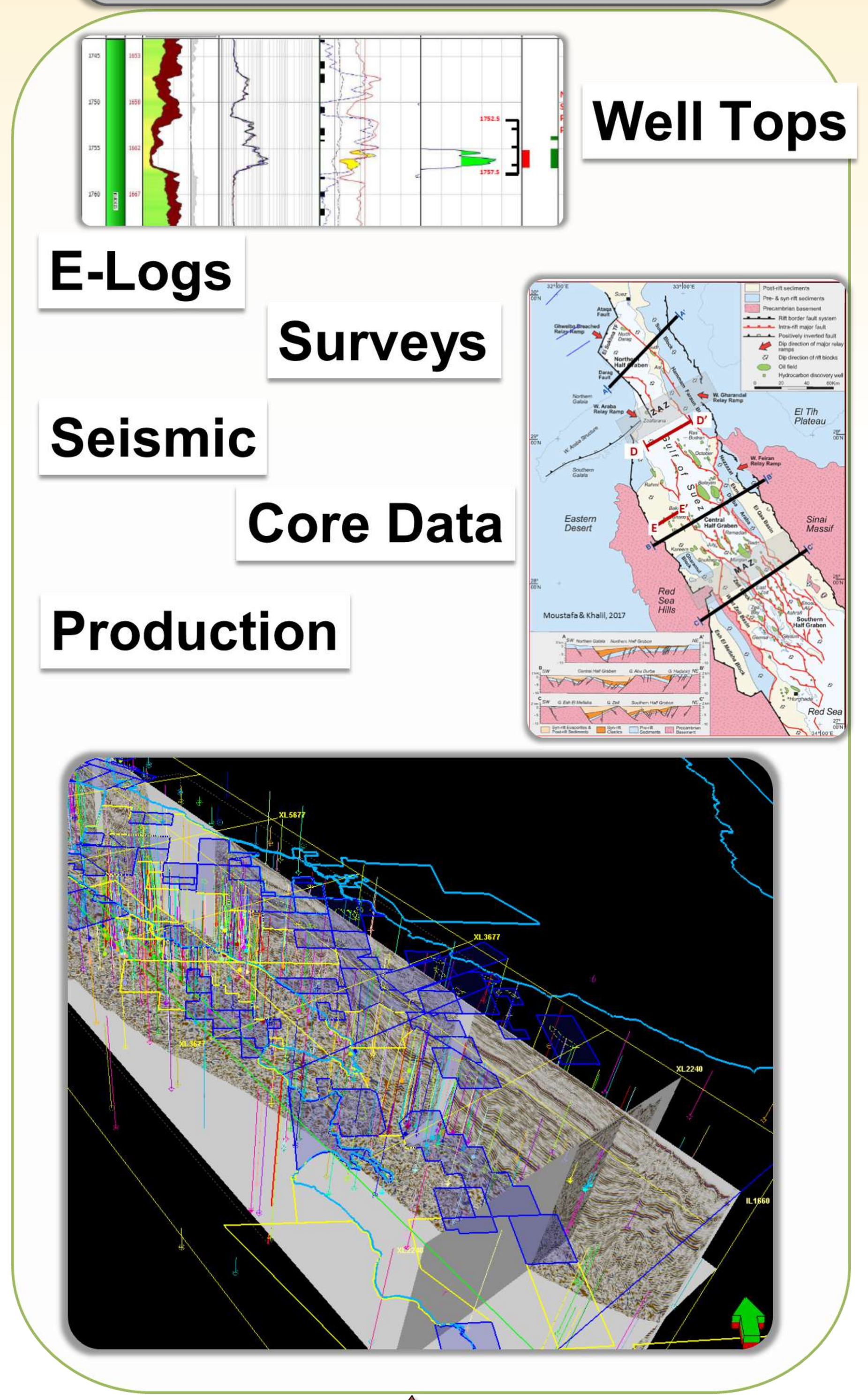
❑ Study methodology&workflow

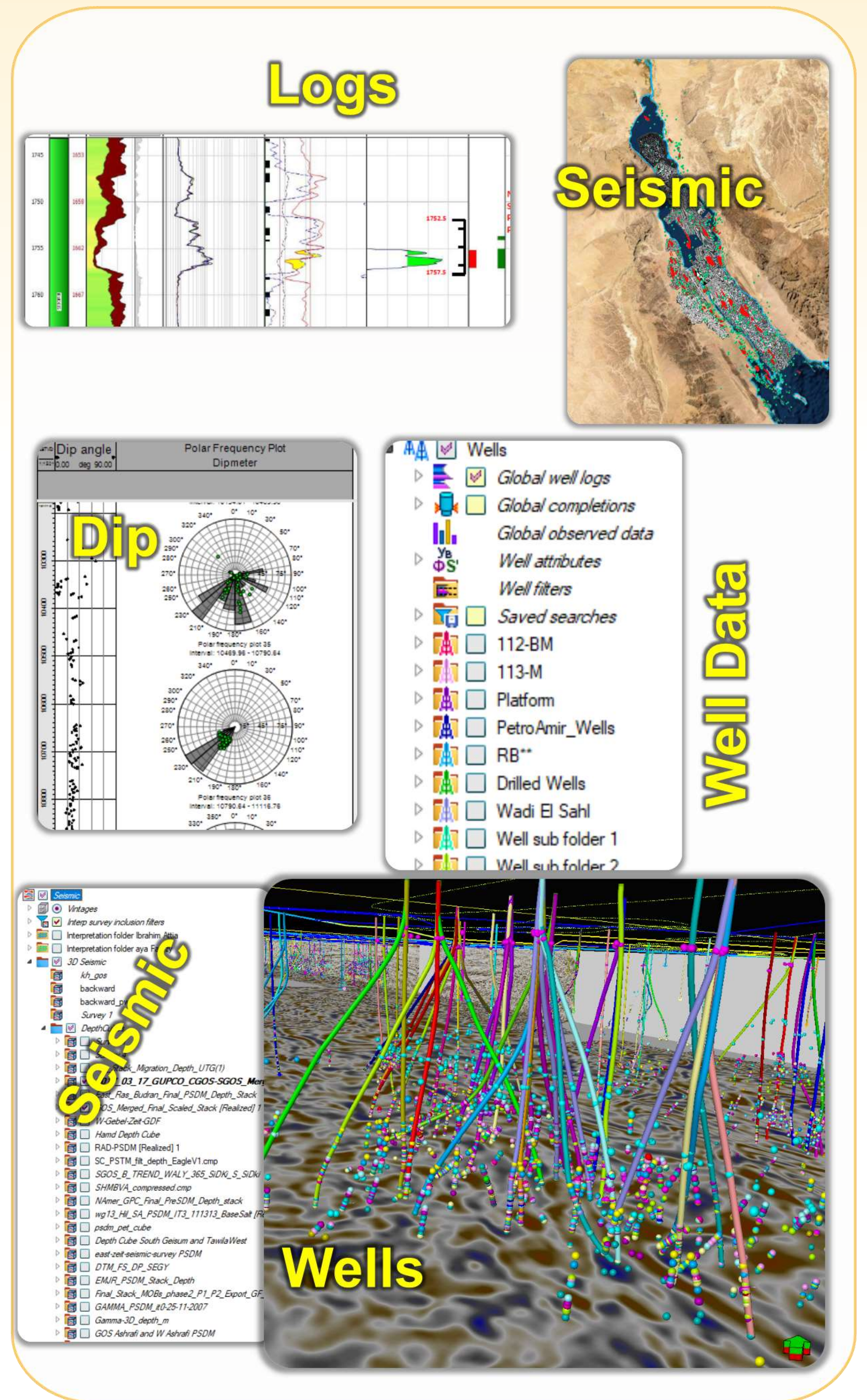


Definition of Study Area in a Regional Context

Data Gathering / Review previous work and literatures

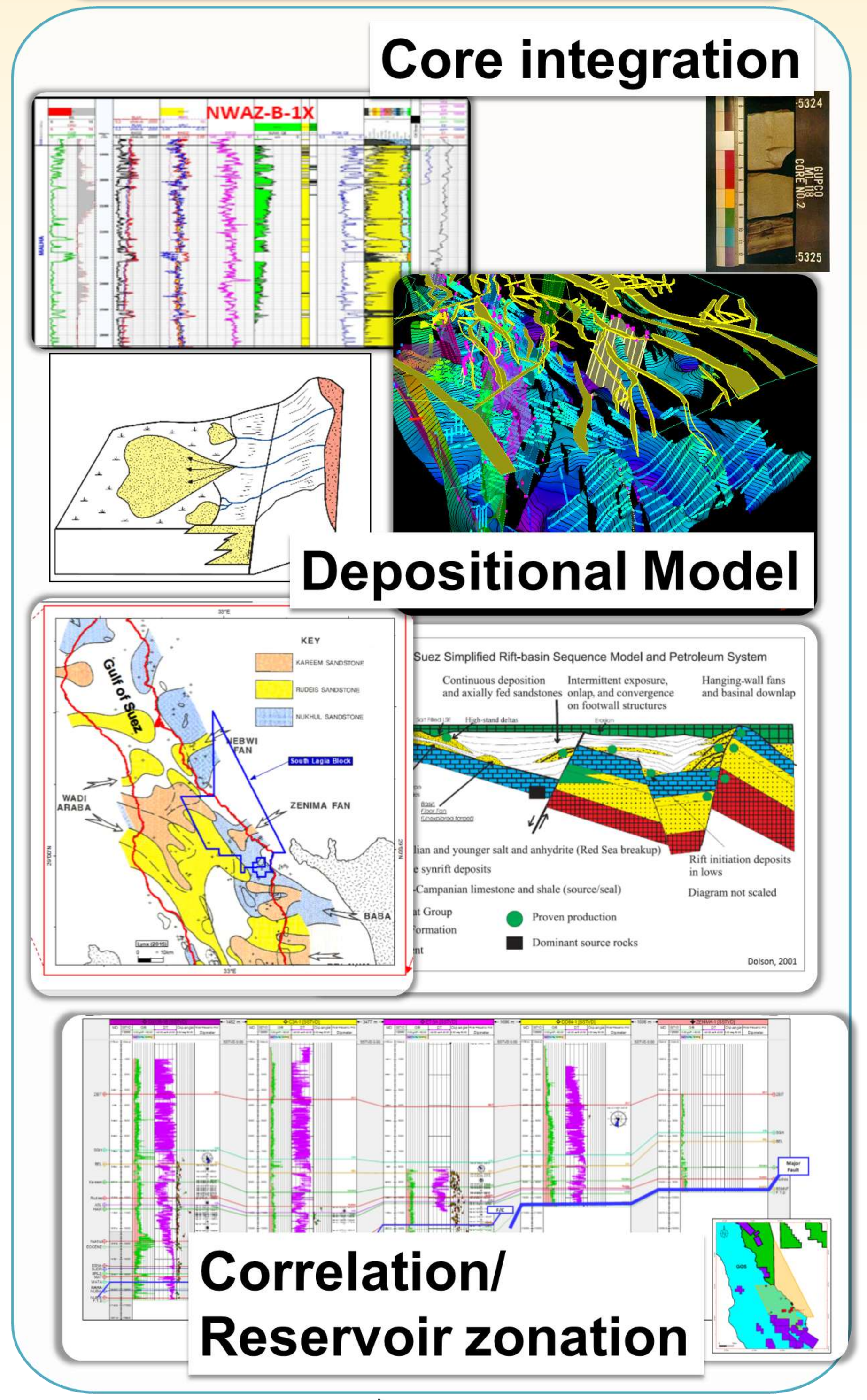
Building Database

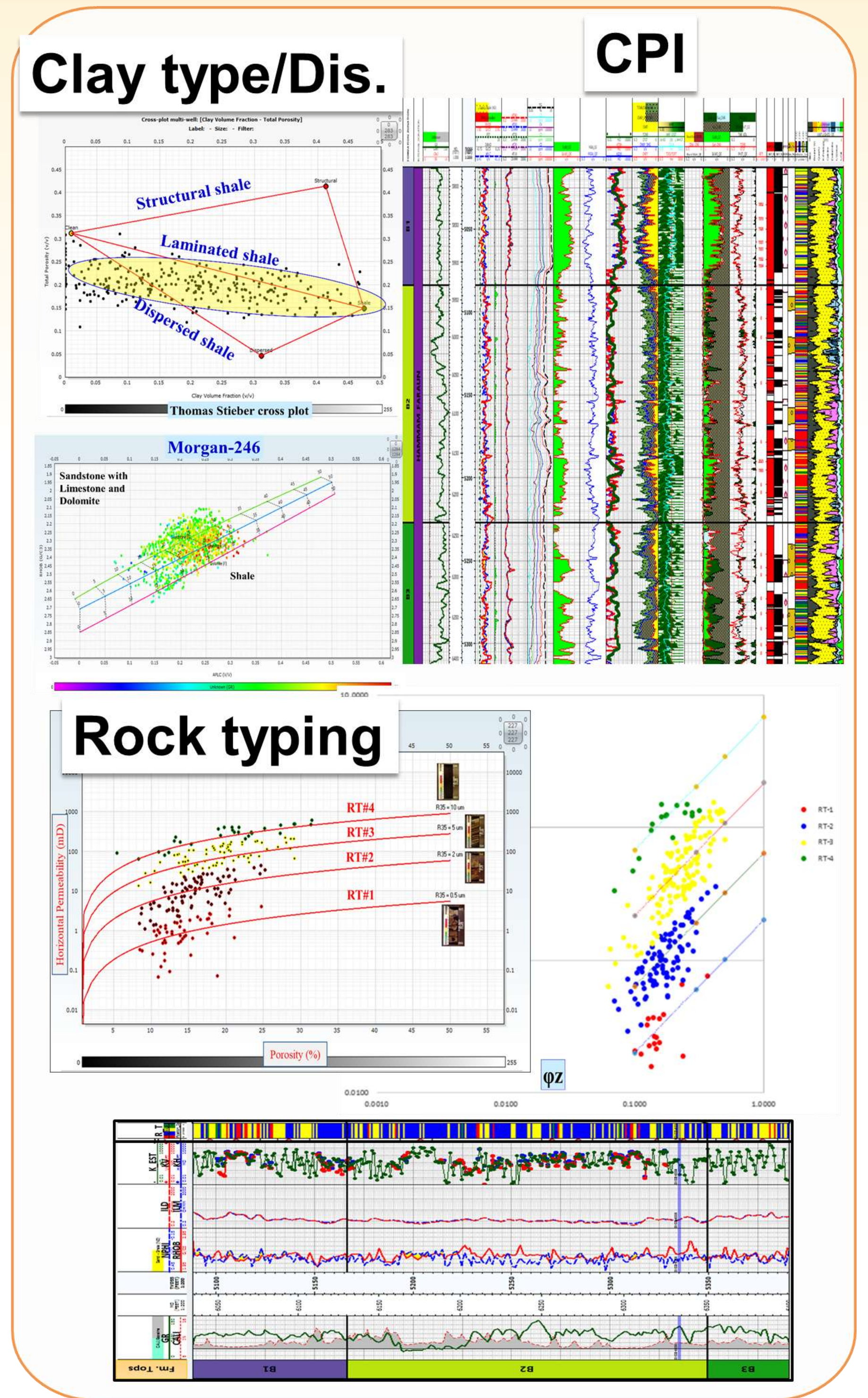




Data loading/conditioning /challenging & Reservoir analysis

Building Geological understanding and conceptual model

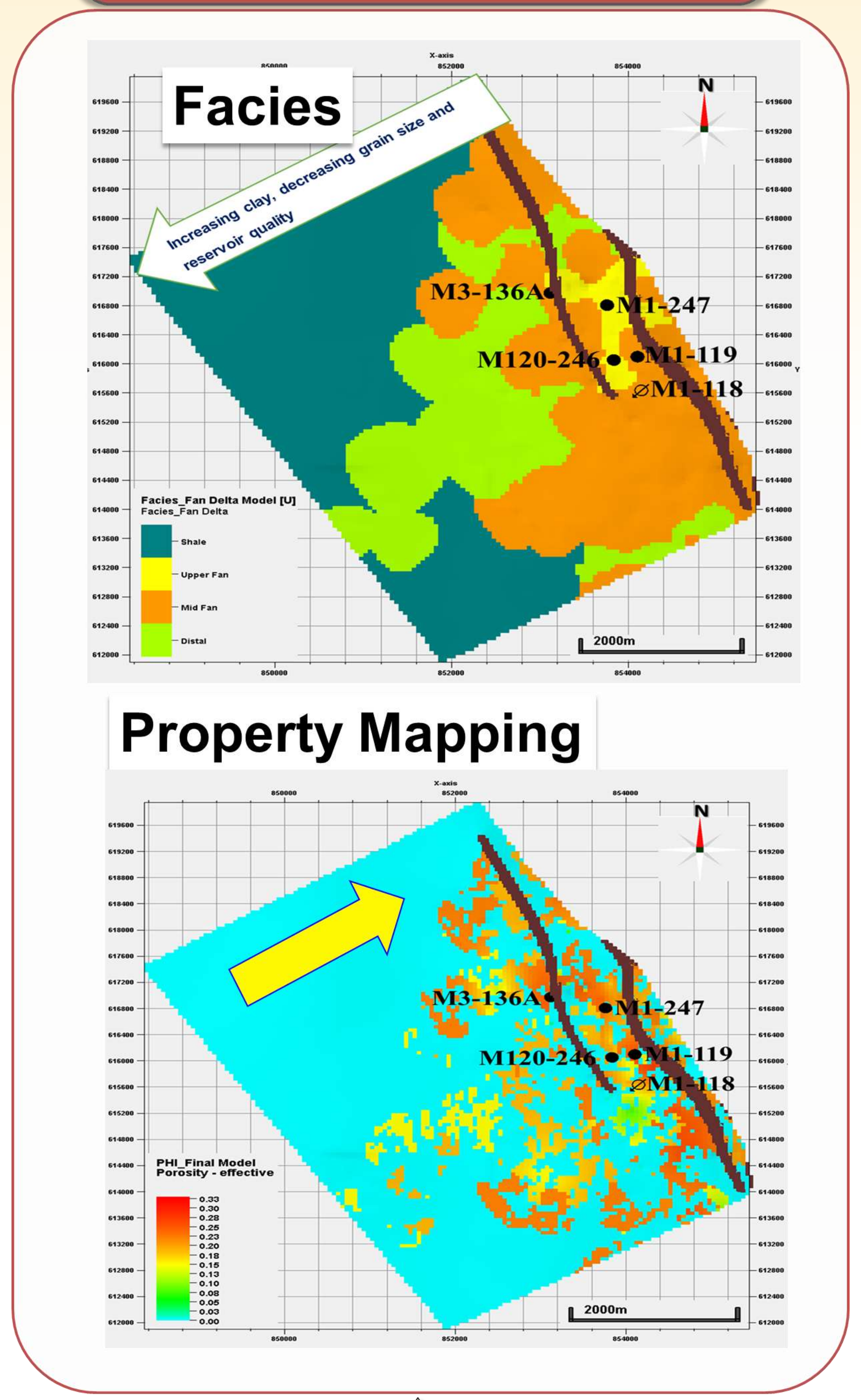




Petrophysical Evaluation

CPI for fluid and rock properties

Property & Facies Mapping



Applied techniques

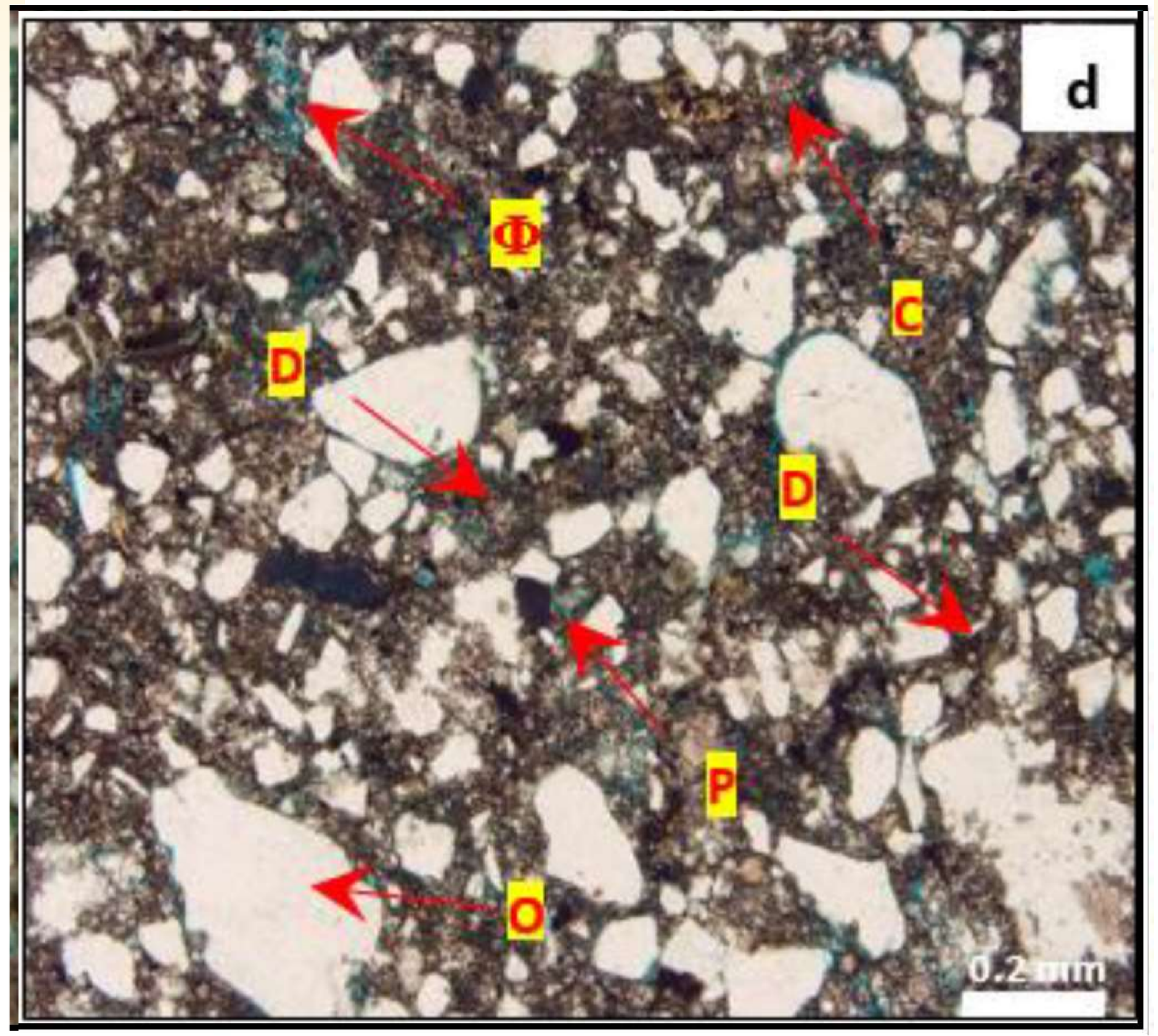
❑ Hammam Faraun reservoir facies

○**Sandstone facies (I);** Good reservoir quality and distributed along Hammam Faraun (B1) and some intervals in (B2) zone.

○**Sandstone facies (II);** Medium to good reservoir quality and distributed across Hammam Faraun (B2 and B1) zones.

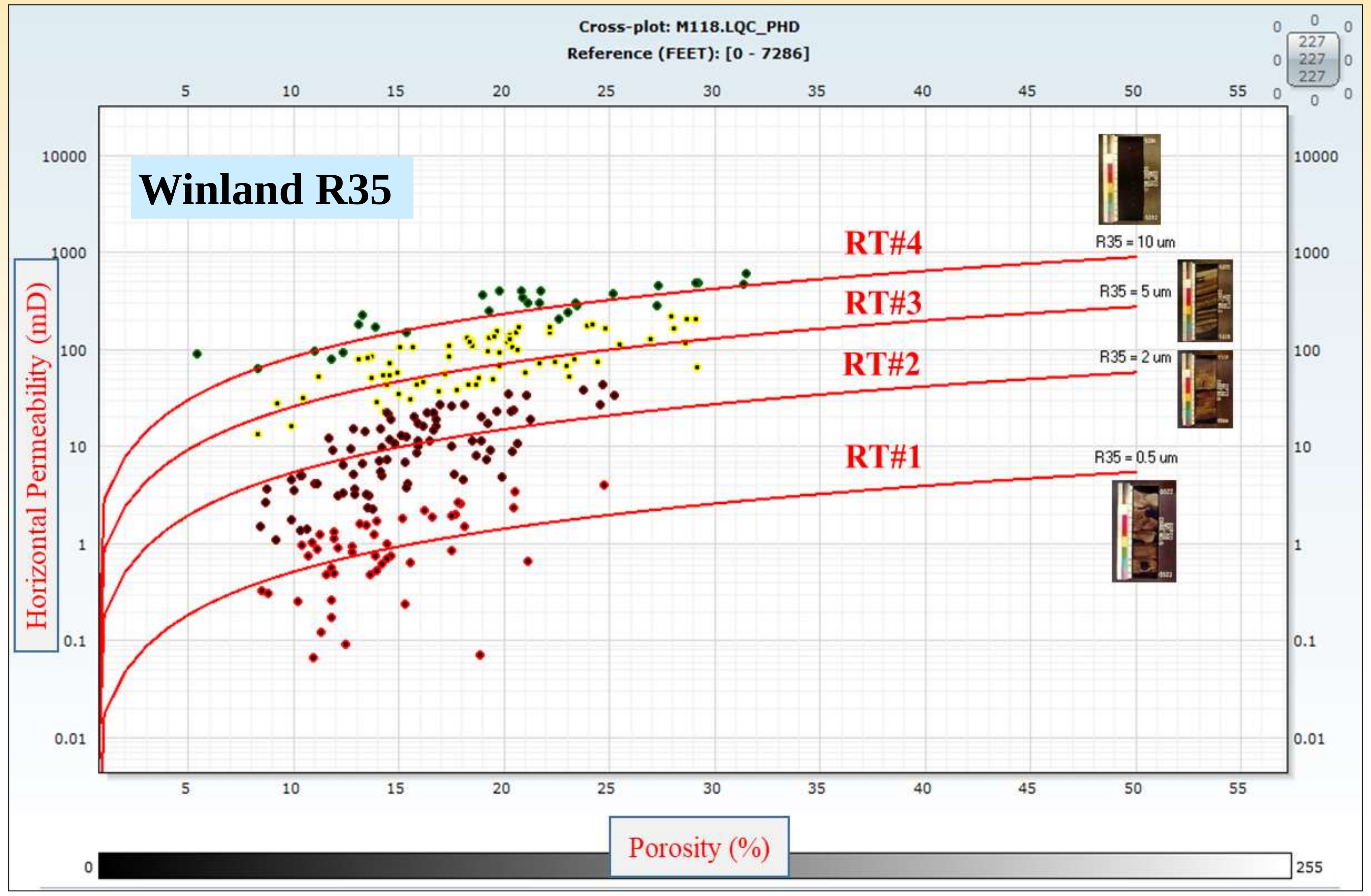
○**Sandstone facies (III);** Medium to poor reservoir quality and common in Hammam Faraun (B3) and some intervals in (B2) zone.

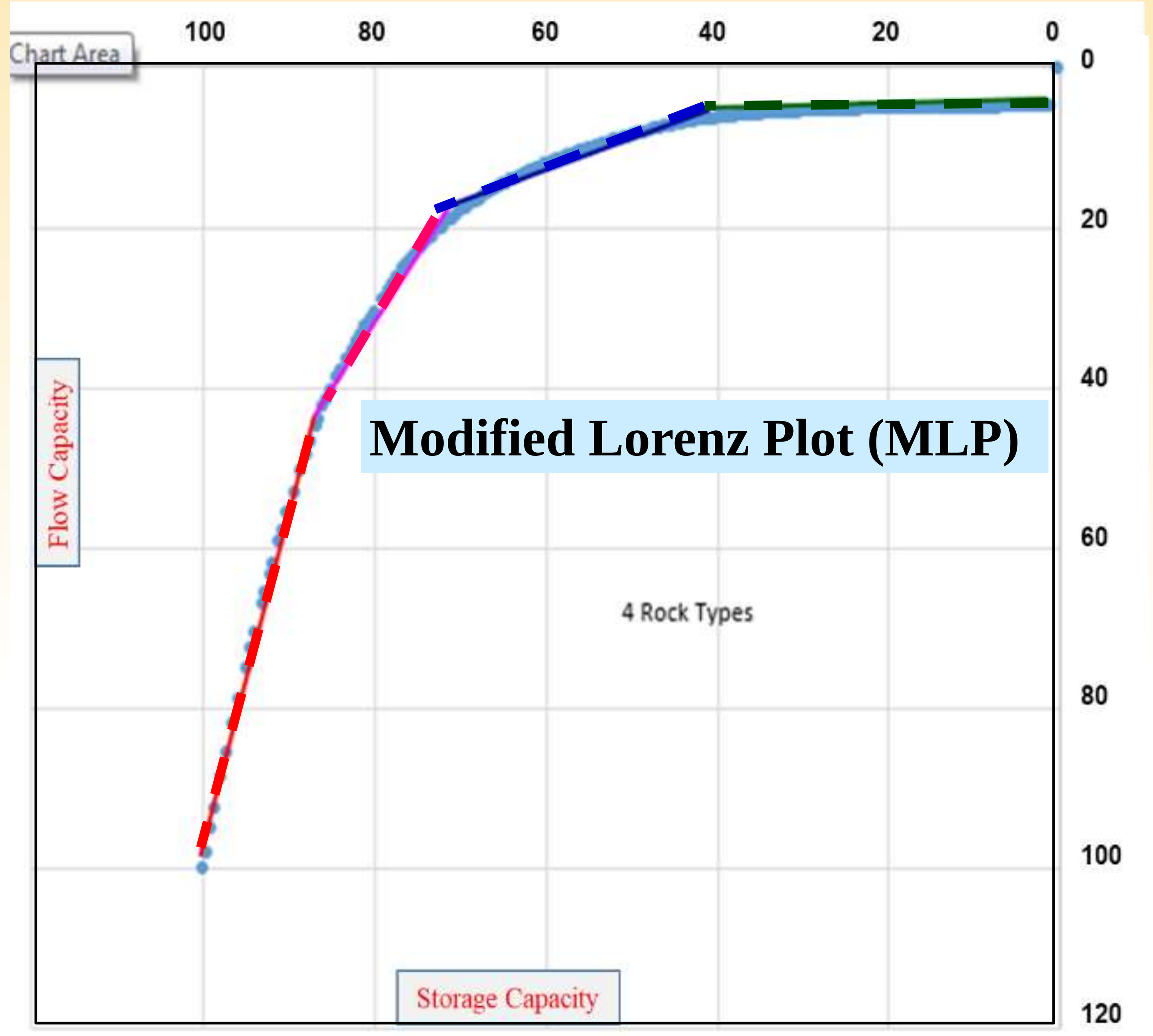
○**Sandstone facies (IV);** Poor reservoir quality and common in Hammam Faraun (B3) zone

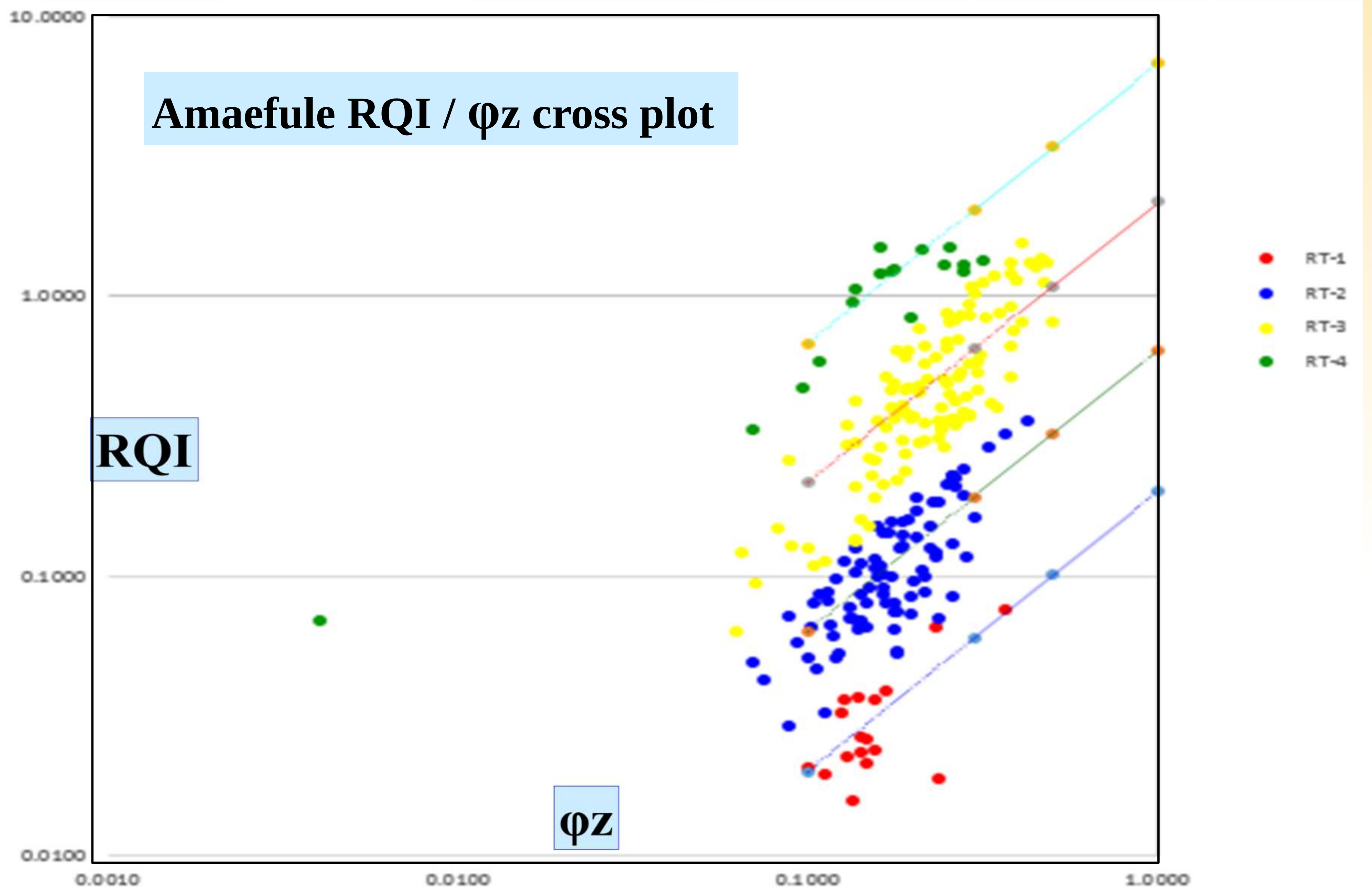


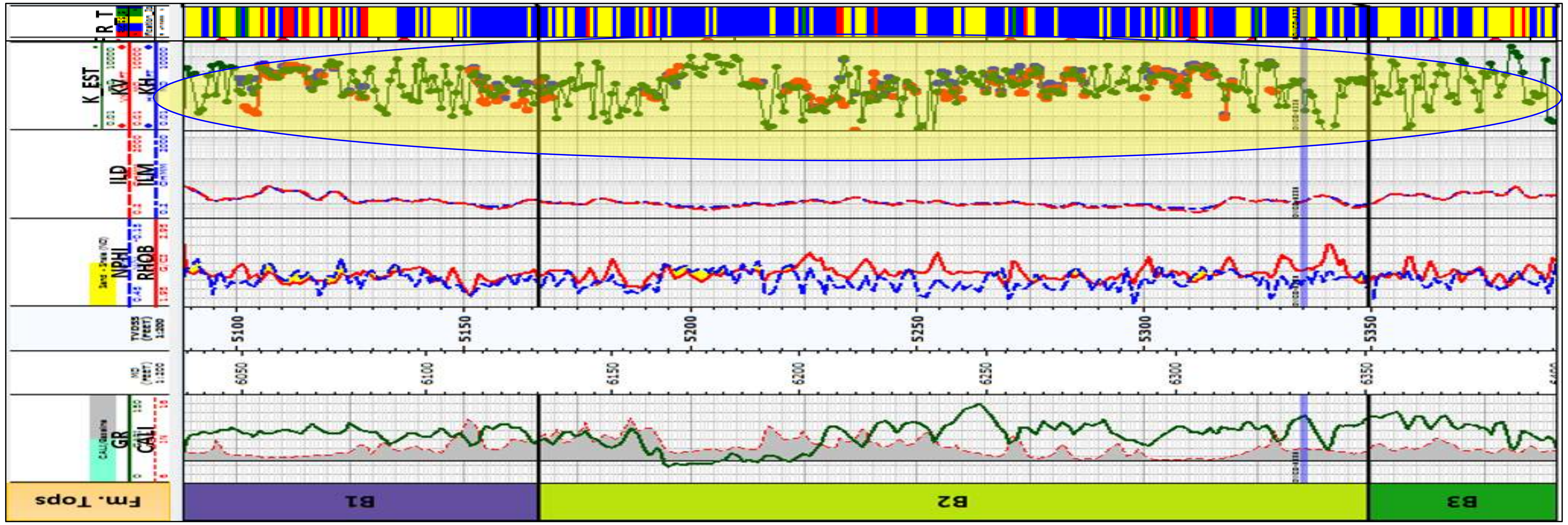
Applied techniques

❑ Hammam Faraun reservoir rock typing





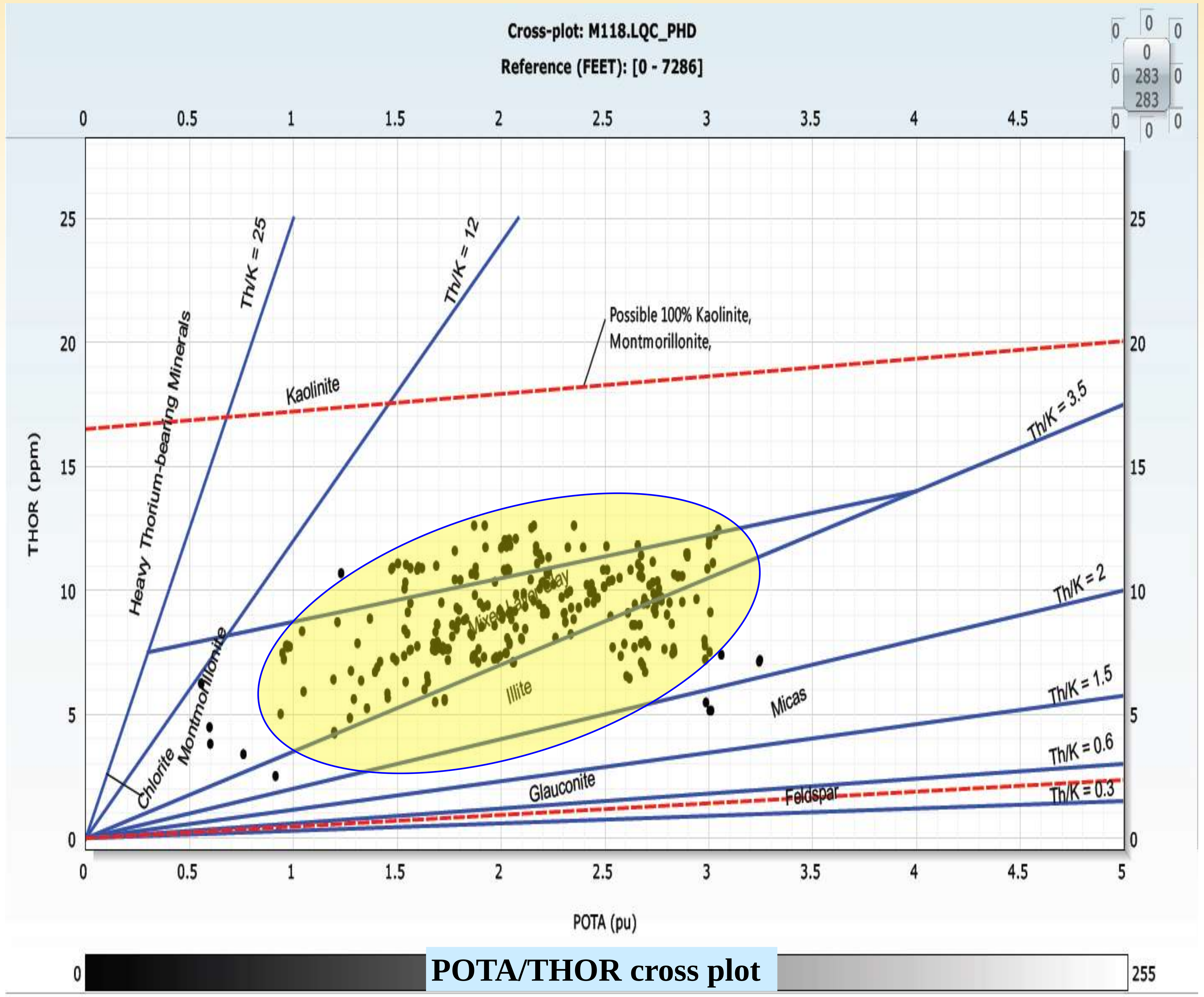




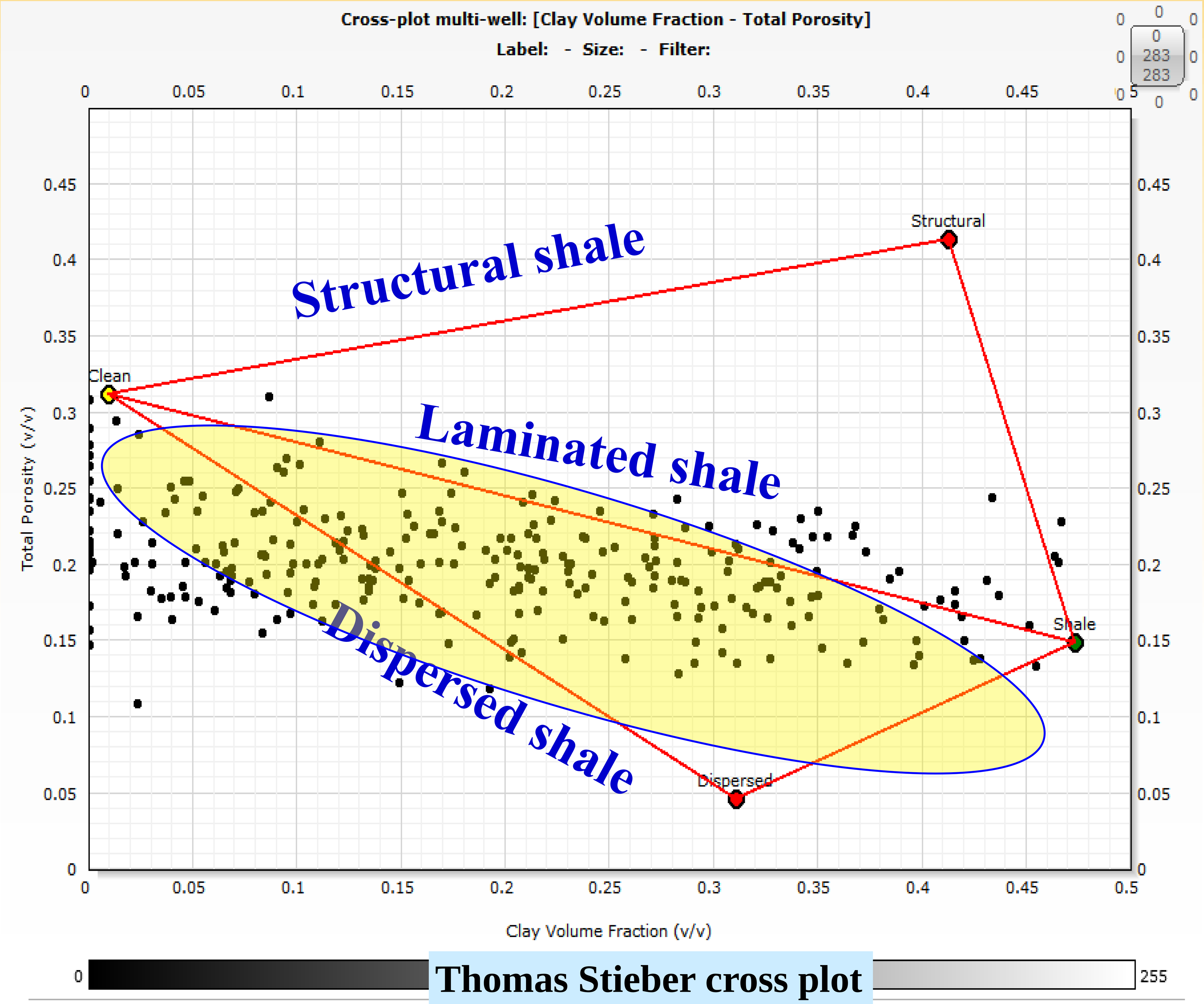
- Hammam Faraun member deal with Four main rock types

Applied techniques

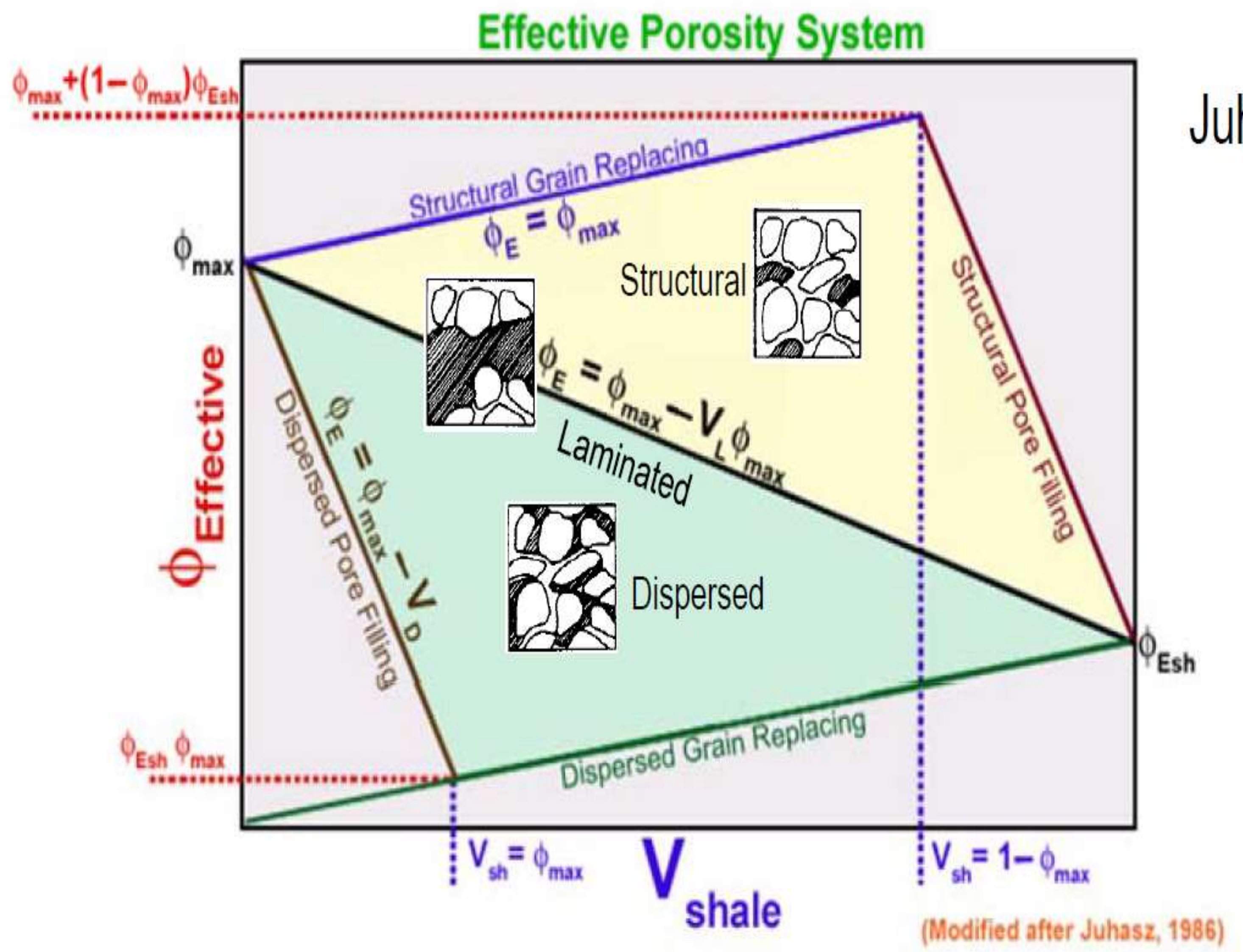
- Hammam Faraun clay types & distributions



POTA/THOR cross plot



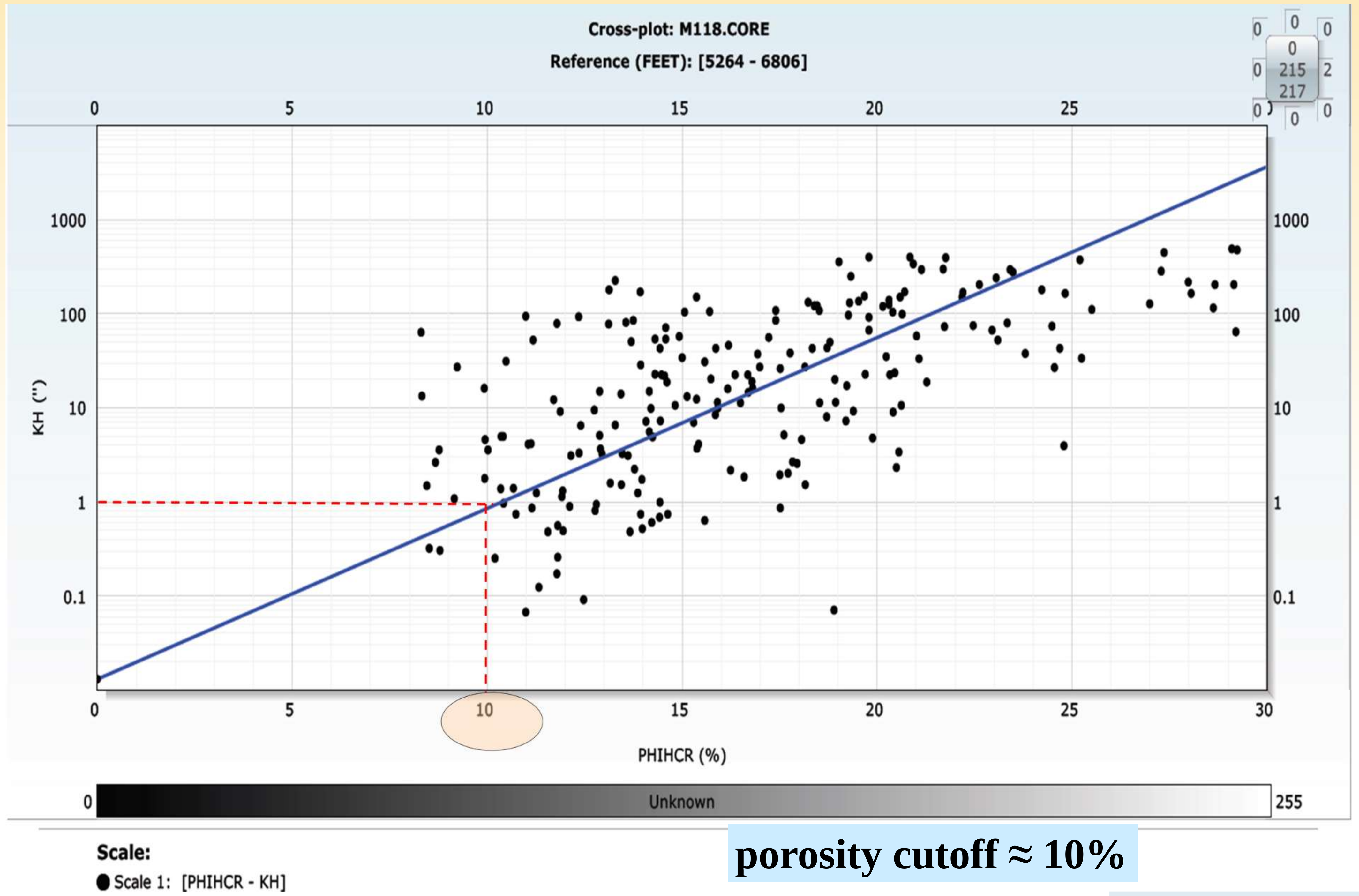
Thomas Stieber cross plot



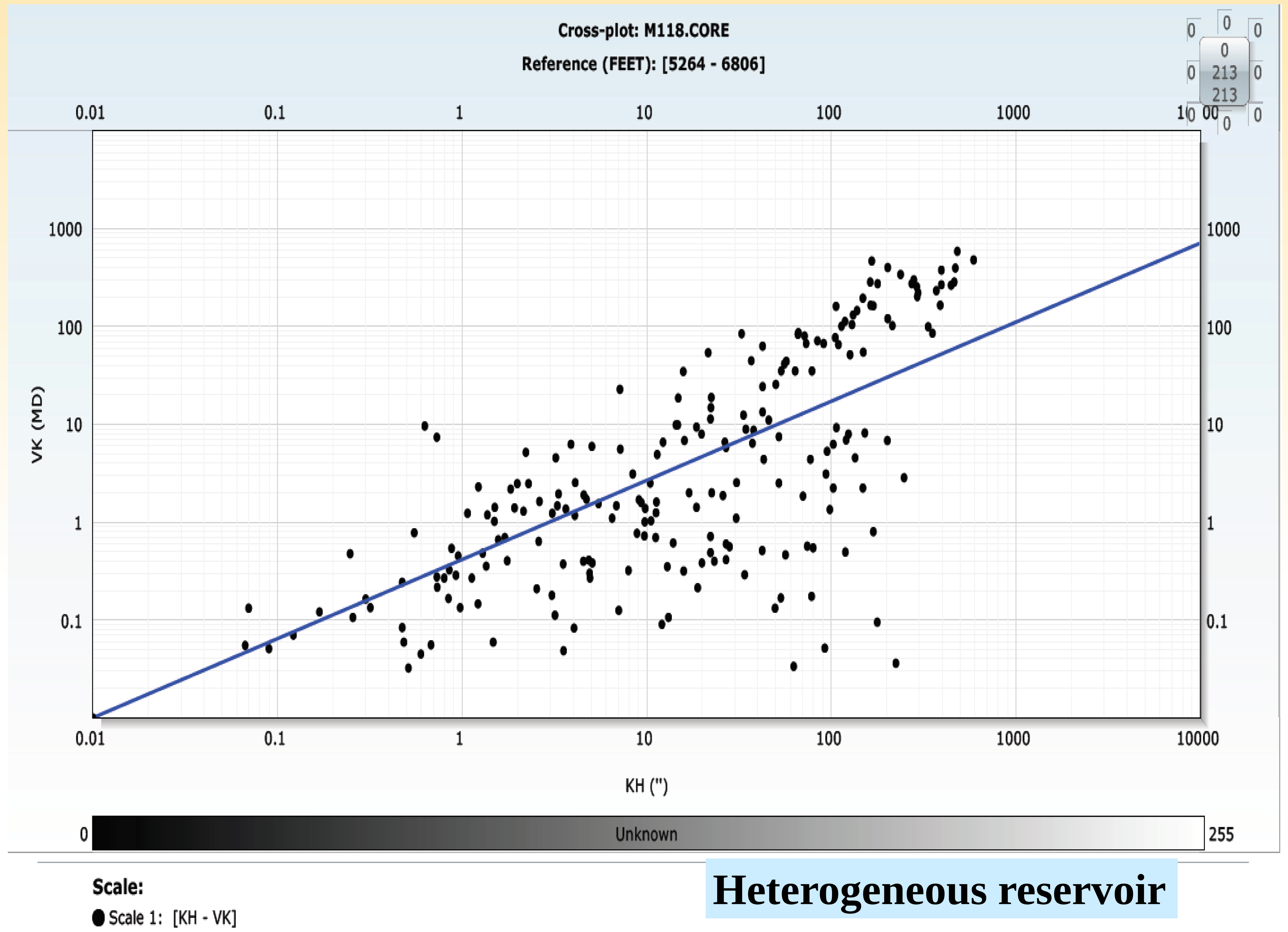
Juhasz plot

Applied techniques

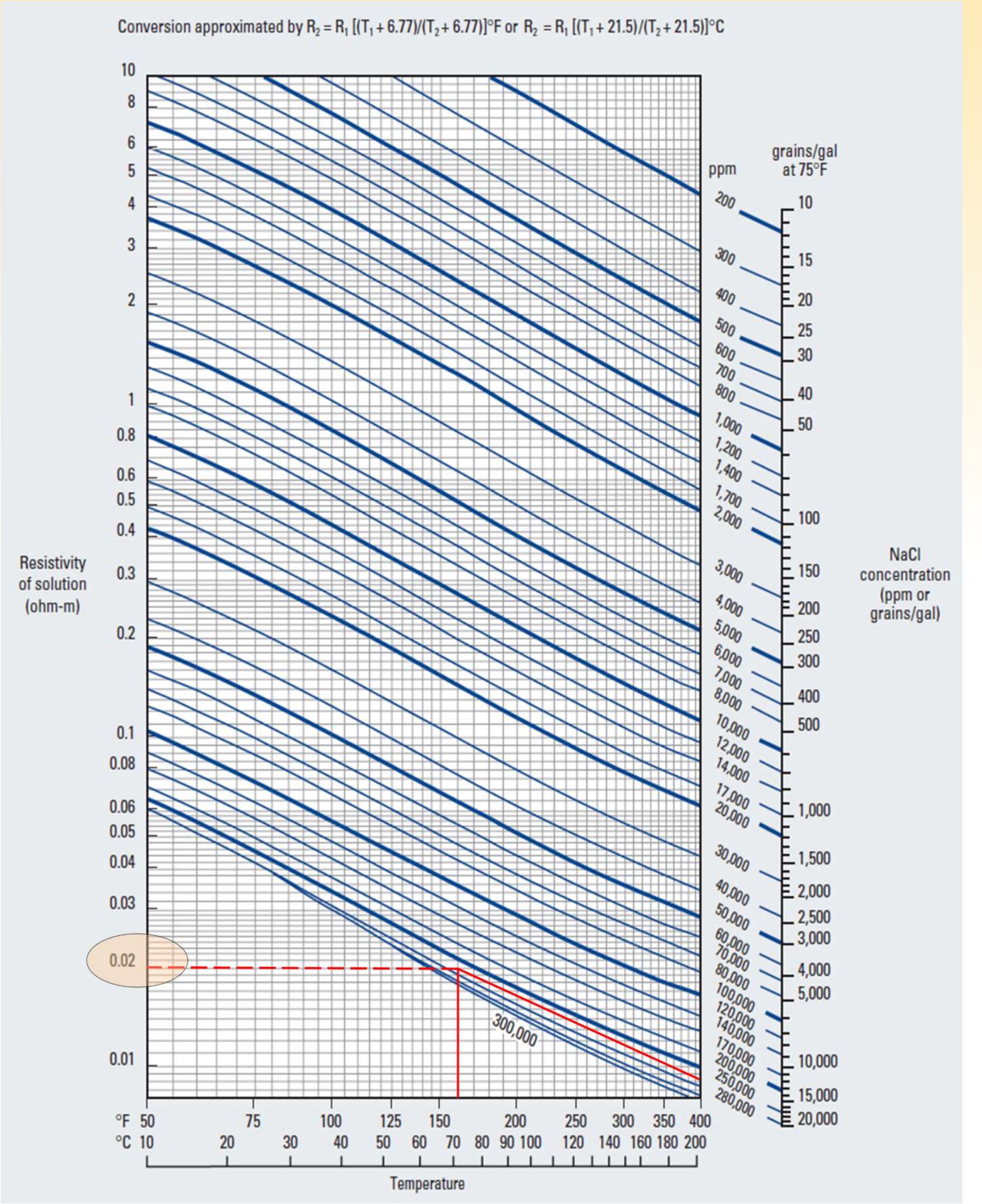
❑ Hammam Faraun petrophysical parameters



porosity cutoff ≈ 10%



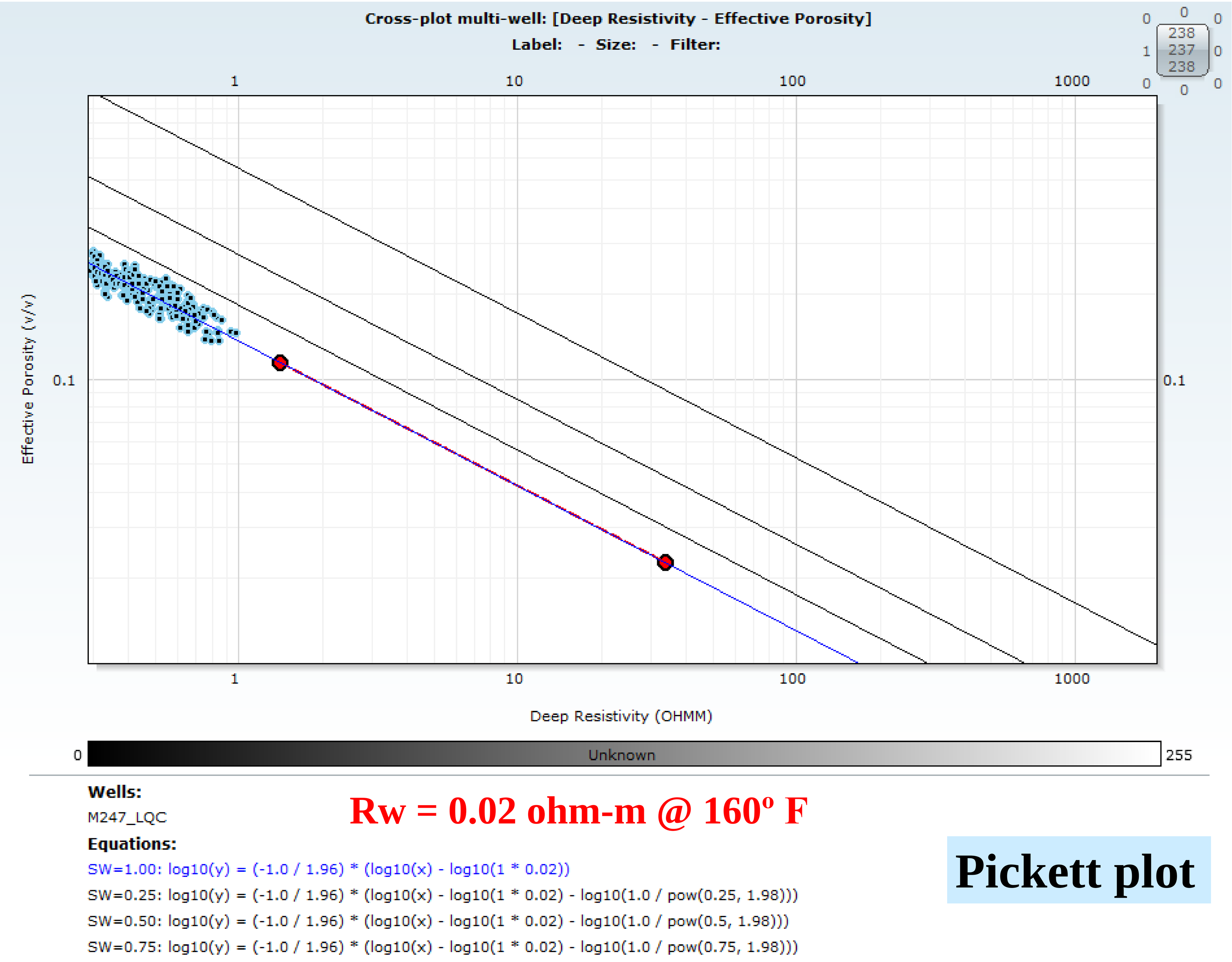
Heterogeneous reservoir



Salinity / Rw cross plot

SCAL Electrical properties

m = 1.96
n = 1.98



Pickett plot

Average chloride (CL^-) from the wellhead sample analysis for different wells is around 140,000 ppm

(the calculated TDS ~ 231,000 ppm).

Rw = 0.02 ohm-m @ 160º F

Applied techniques

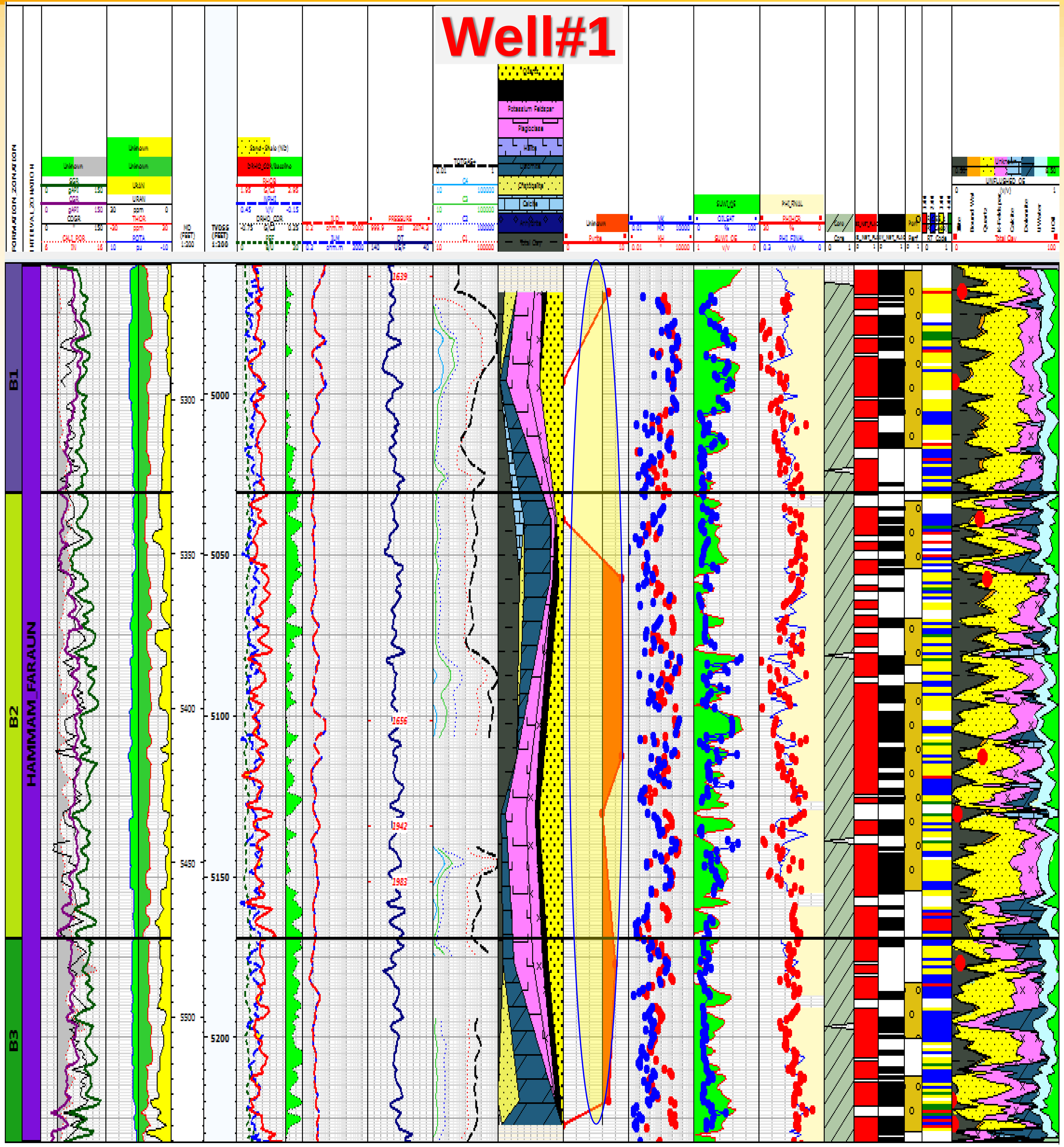
- Hammam Faraun petrophysical evaluation

Hammam Faraun
- **Net Pay : 141 ft**
- **Avg. POR. (Pay) : 18 %**
- **Avg. Sw (Pay) : 51 %**

- XRD analysis

SAMPLE IDENTIFICATION NUMBER	KAOLINITE	CHLORITE	ILLITE	SMECTITE	MIXED-LAYER ILLITE/SMECTITE	% EXPANDABLE LAYERS		TOTAL CLAY	QUARTZ	POTASSIUM FELDSPAR	PLAGIOCLASE	CALCITE	DOLOMITE	PYRITE	CRISTOBALITE	TRIDYMITE	CLINOPTILOLITE	CELESTITE	ANHYDRITE	HALITE
5265.2'		1	3	6				10	25	12	27			7	19		P			
5294.1'	1		1	1				3	36	18	33		10							
5338.9'	3	1	12		10	45		26	10	2	6	14	41	Tr						1
5358.2'	7	3	4	17	2	20		33	7		4		39	9	8					
5415.7'	6	2	6	20	6	40		18	29	14	30			9						
5434.1'	1	1	1		2	75		5	37	14	31		7	6						
5482.7'	Tr	Tr	2	6				8	23	15	29		17	8						
5527.0'	Tr	Tr	Tr	Tr	Tr	40		Tr	4	1	1		54	7	33					
5534.8'	1	1			Tr	20		2	2				92					P	4	

2002, Converted as Kareem injector

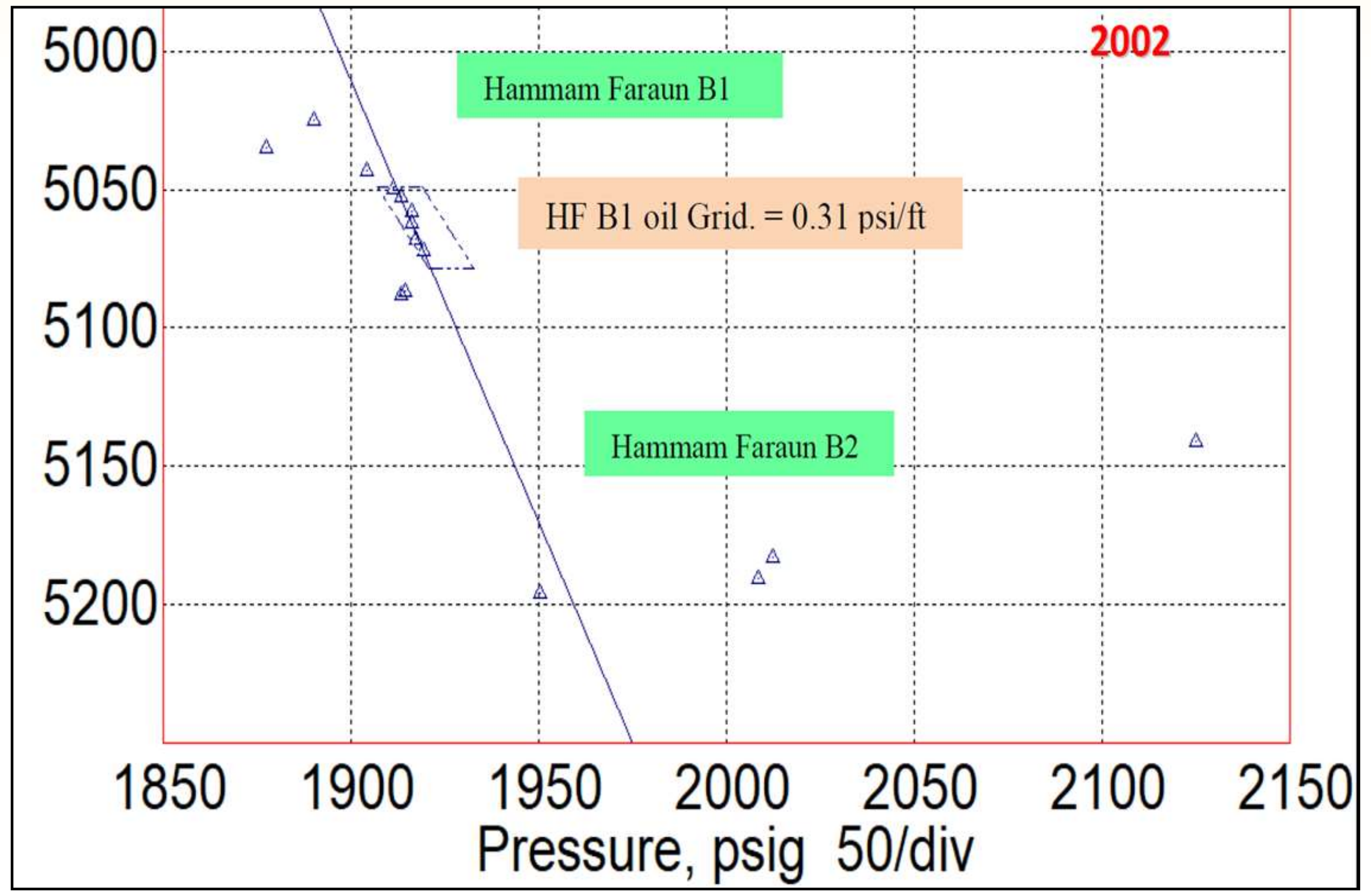


Applied techniques

❑ Hammam Faraun petrophysical evaluation

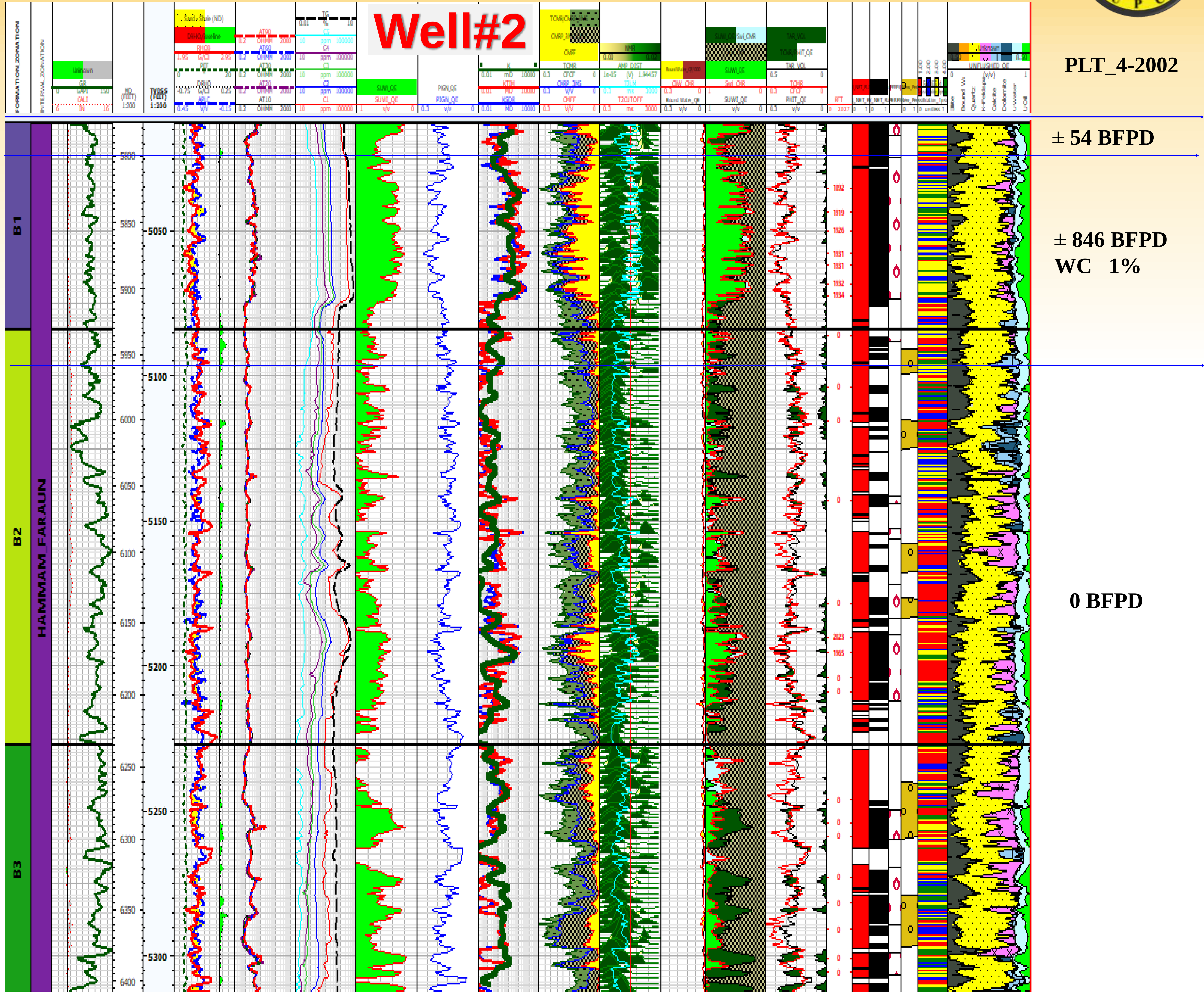
Hammam Faraun
- **Net Pay :** 162 ft
- **Avg. POR. (Pay) :** 19 %
- **Avg. Sw (Pay) :** 47 %

902 BFPD W/ Traces W.C (1.2%)



Zone	Depth		PLT	Remarks
	From "ft"	To "ft"	Oil Rate BOPD	
B1	5576	5785	± 54	With 1.2 % water cut
	5801	5908	± 846	
B2	5929	5940		
	6058	6063	0	
	6082	6089		
	6123	6146		
	6158	6204		
B3	6280	6300		
	6320	6360		
	6380	6395		

2002, Completed as Belayim producer



Applied techniques

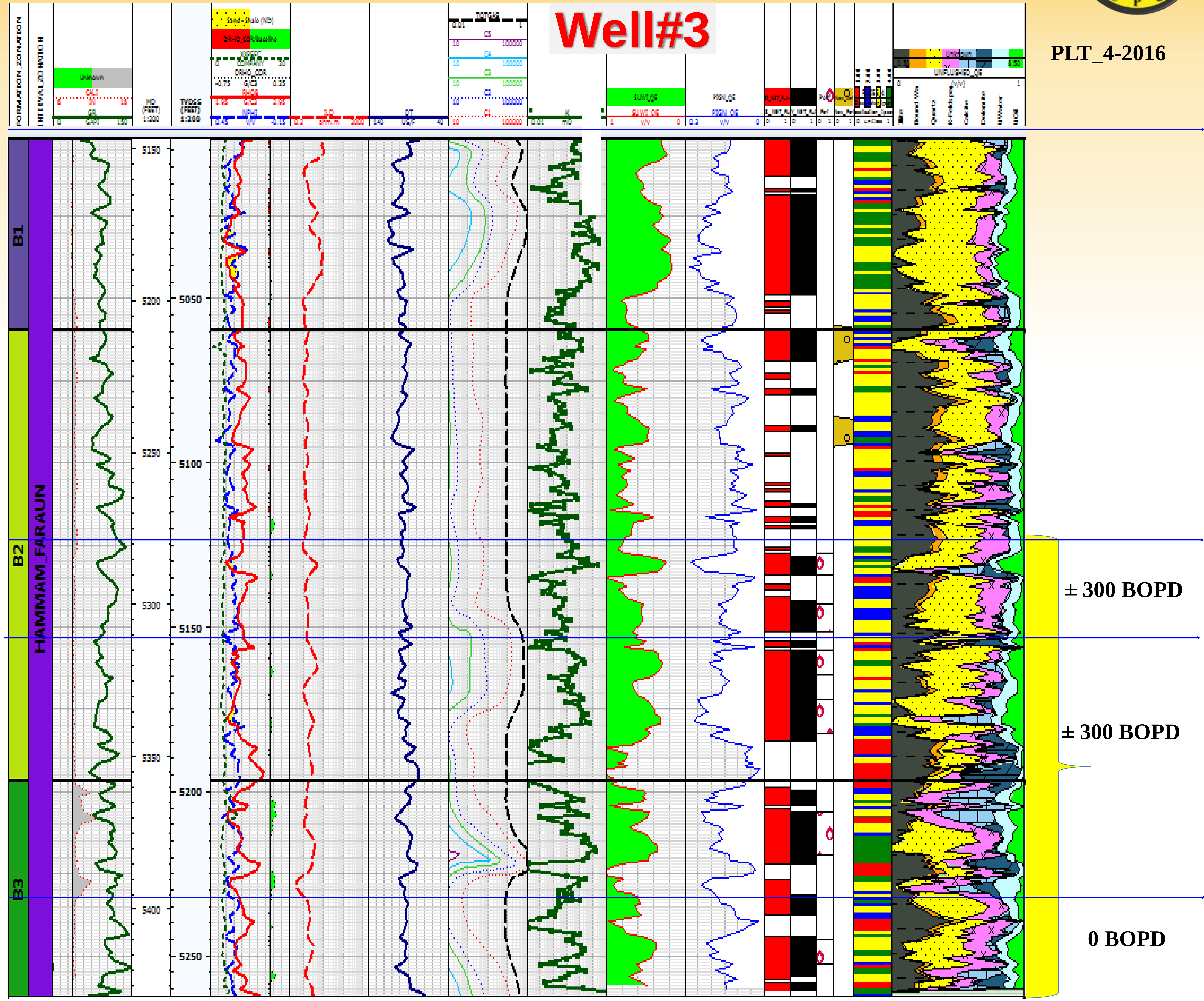
❑ Hammam Faraun petrophysical evaluation

Hammam Faraun
- **Net Pay : 146 ft**
- **Avg. POR. (Pay) : 19 %**
- **Avg. Sw (Pay) : 42 %**

1200 BFPD W/ Traces W.C (3%)
From LRP (Thinly Bedded Sandstone)

Zone	Depth		PLT	Remarks
	From "ft"	To "ft"	Oil Rate BOPD	
B1	5148	5154	-	Isolated between two straddle Packer (Closed intervals)
	5165	5172	-	
	5176	5198	-	
B2	5283	5289	± 300	
	5300	5308		
	5315	5322	± 300	
	5331	5341		
B3	5368	5381		
	5410	5417	0	

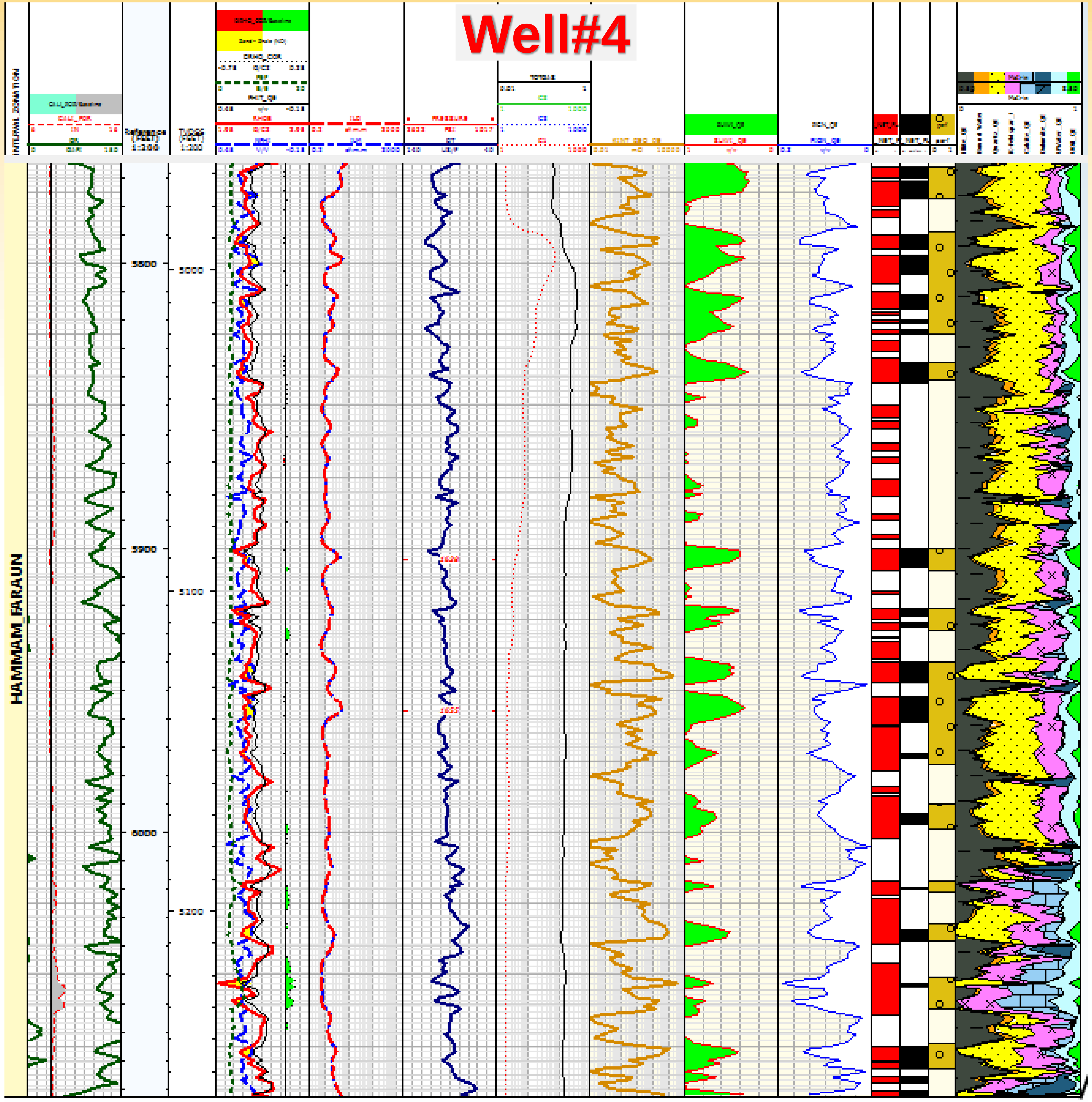
2015, Converted as Belayim producer



Applied techniques

- Hammam Faraun petrophysical evaluation

1600 BFPD W/ Traces W.C

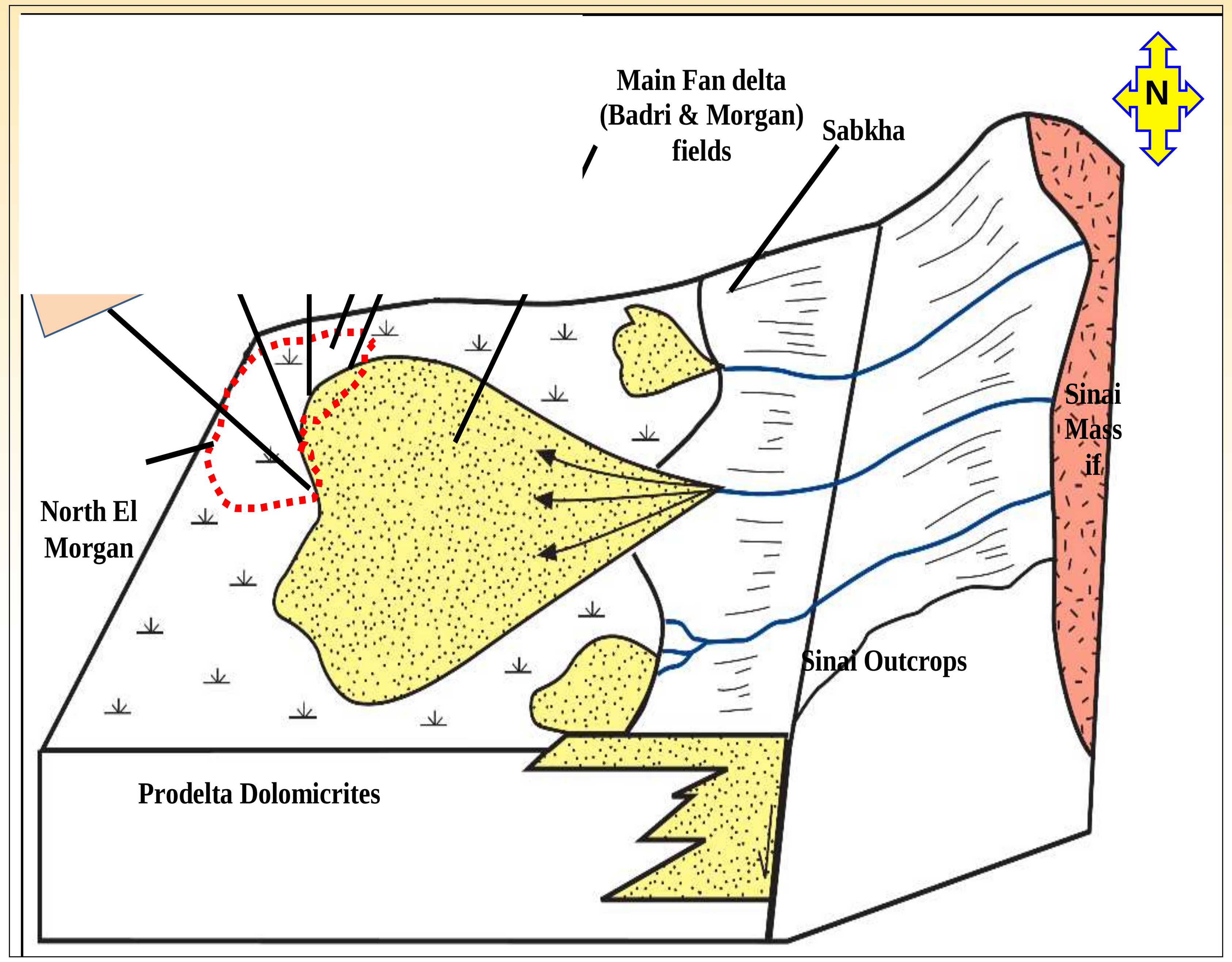


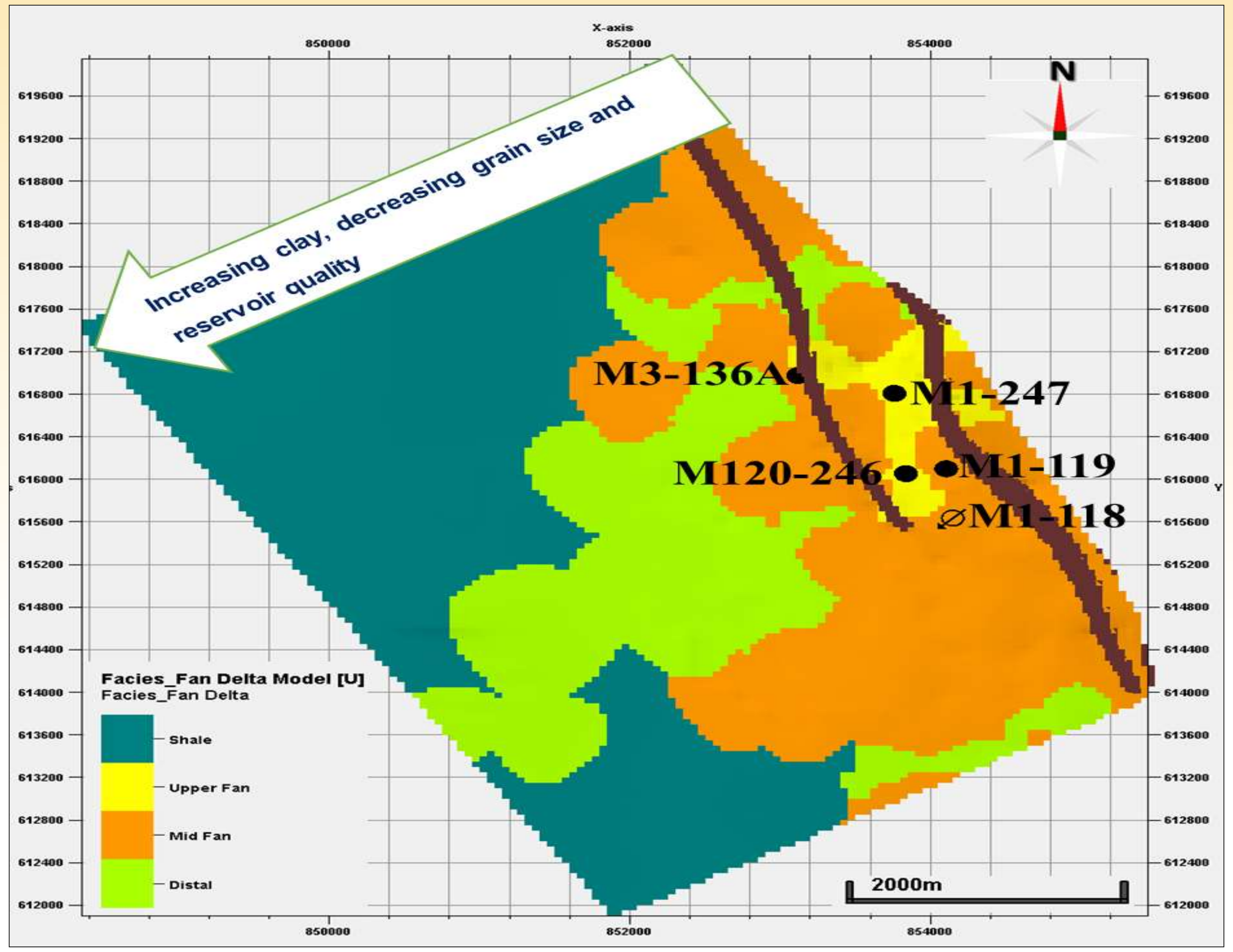
- The LRP appear to be due to the fine grained sand which lead to presence of micro-porosity, Thin lamination and presence of conductive mineral (Pyrite).

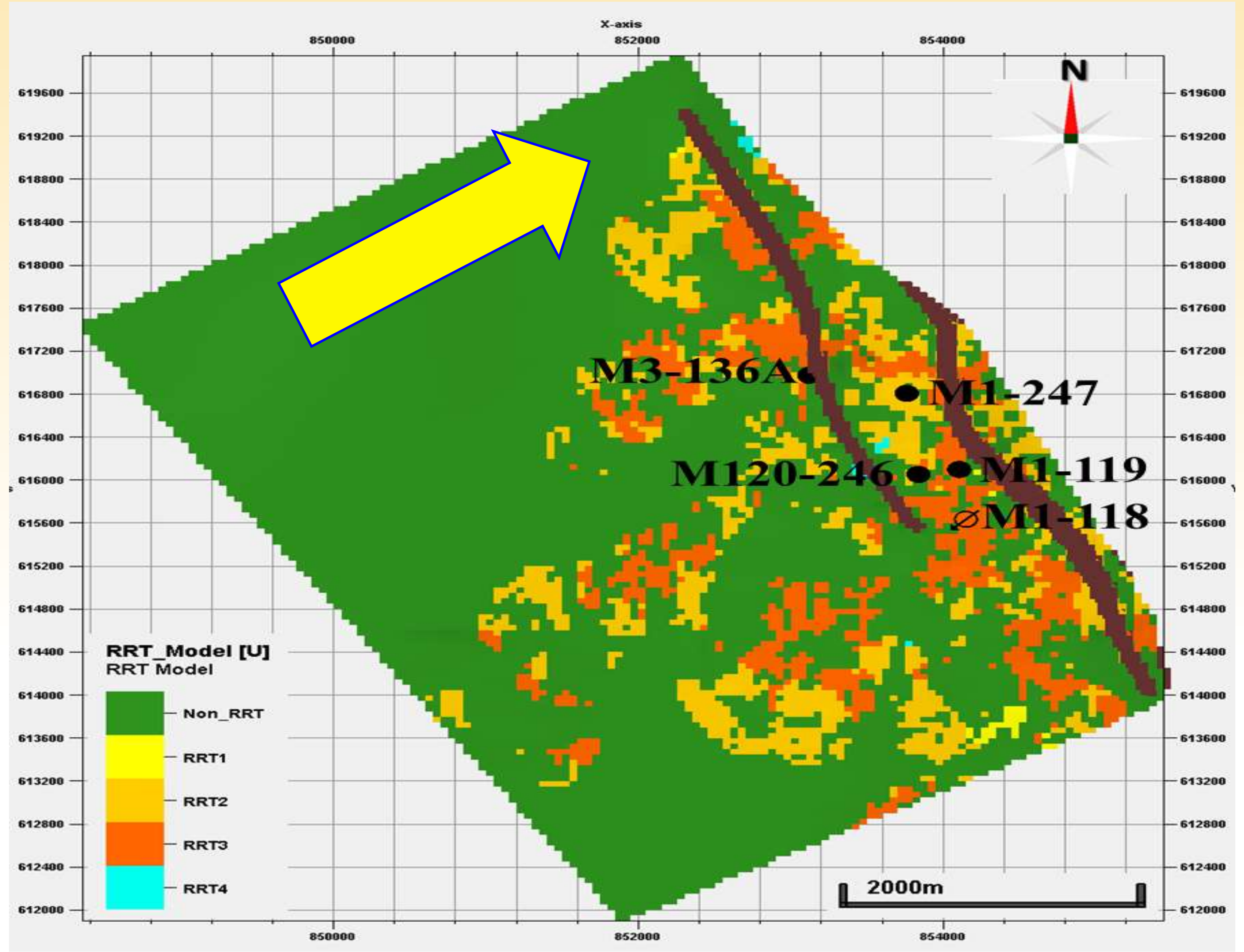
2018, Completed as Belayim producer

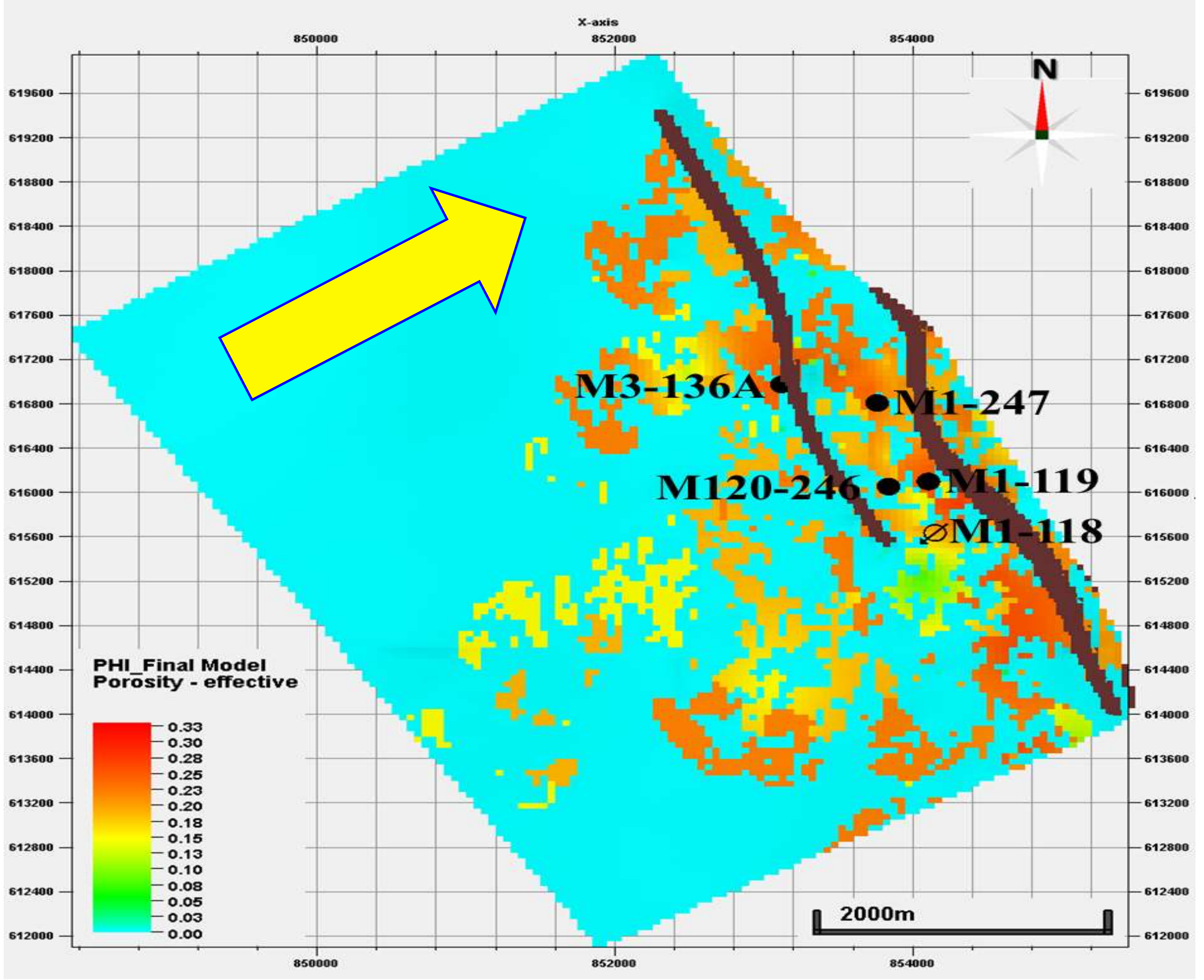
Applied techniques

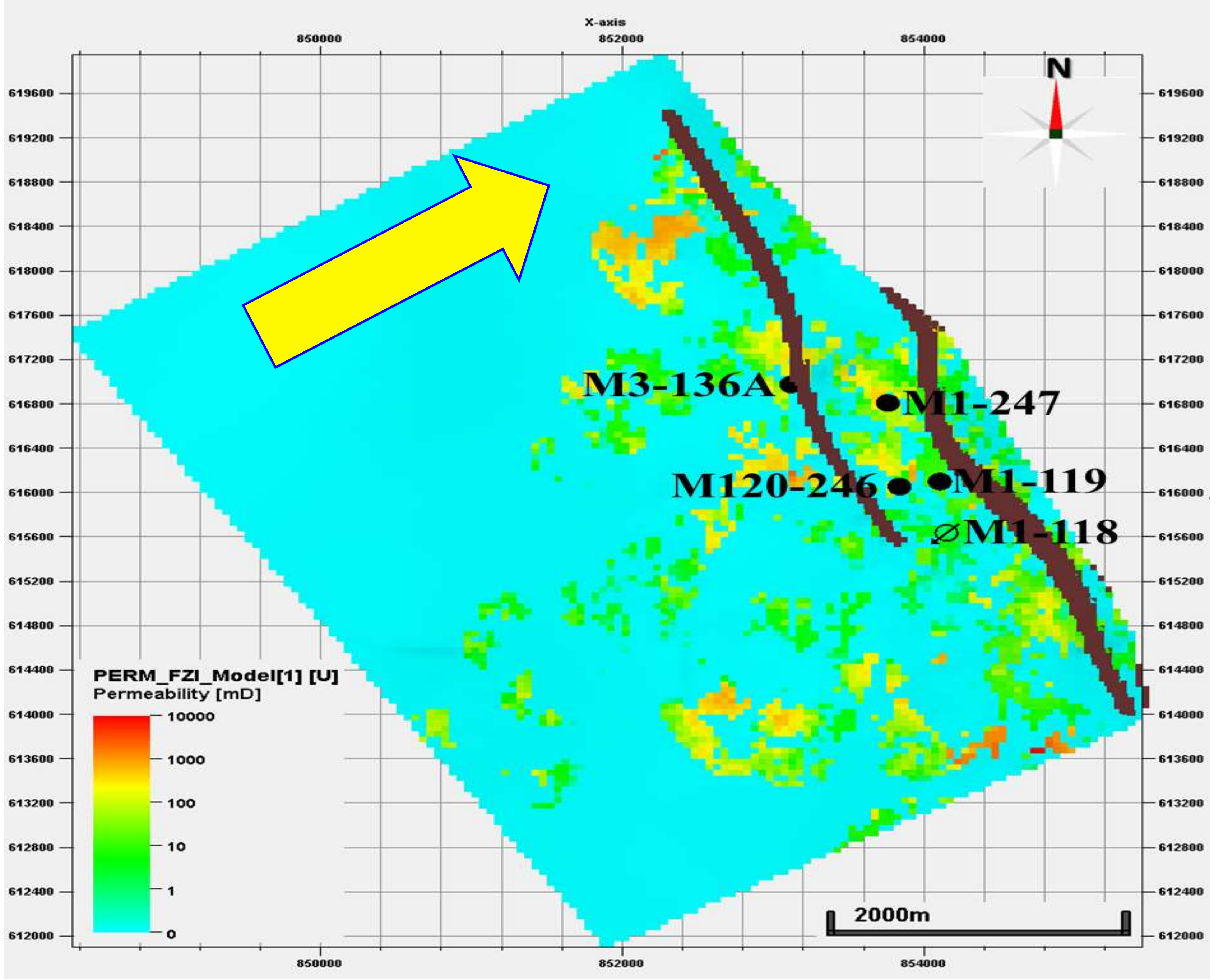
❑ Hammam Faraun reservoir facies and property maps

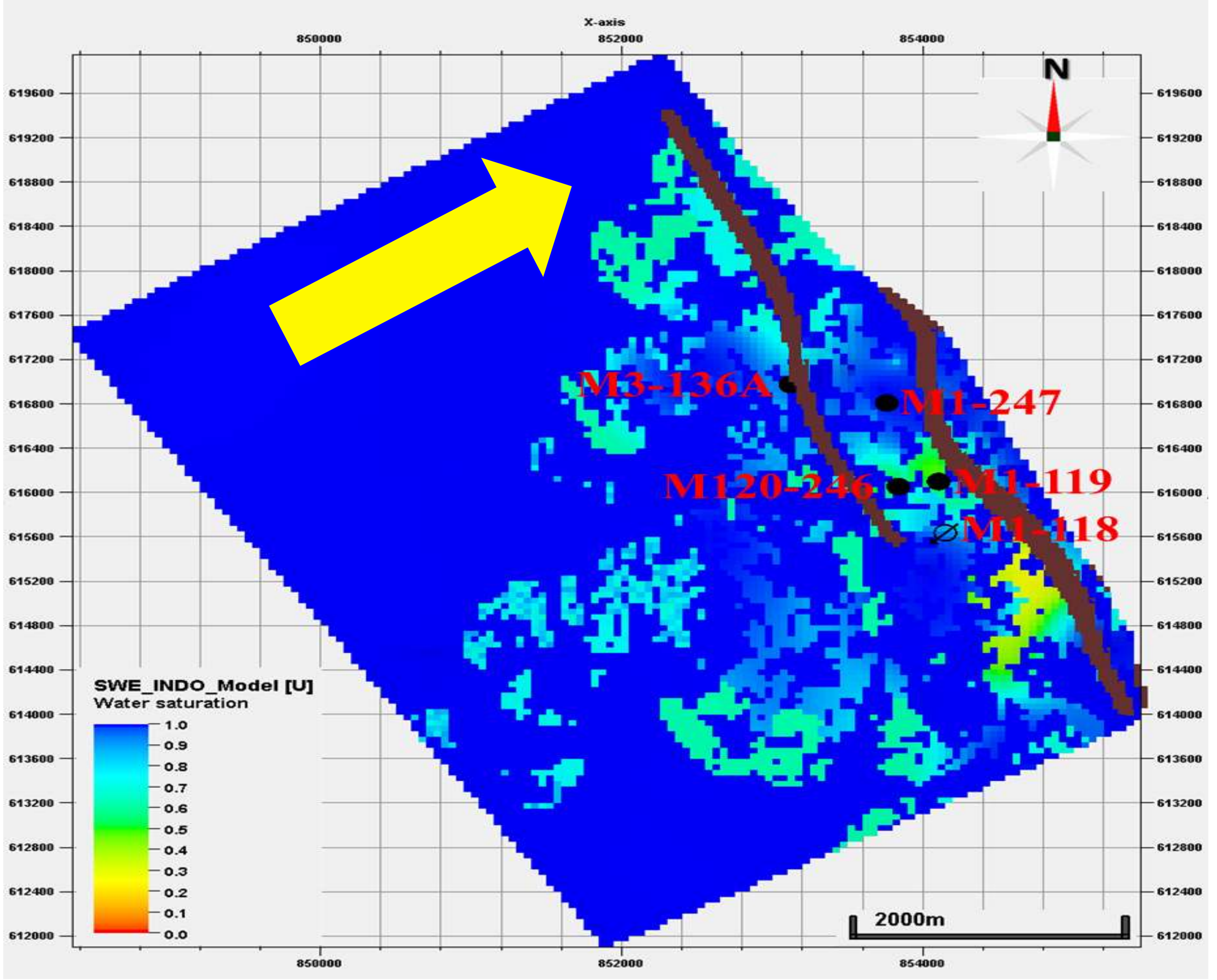












Summary & Conclusions

- Hammam Faraun reservoir clay distribution is a mixed-type in form of laminated and dispersed based on Thomas-Steiber’s triangle plot which are one of causes for low resistivity pays.

- Based on Winland (R35), Amaefule rock typing method and petrological core description; Hammam Faraun reservoir divided into four different rock types: RT#1, RT#2, RT#3 & RT#4.

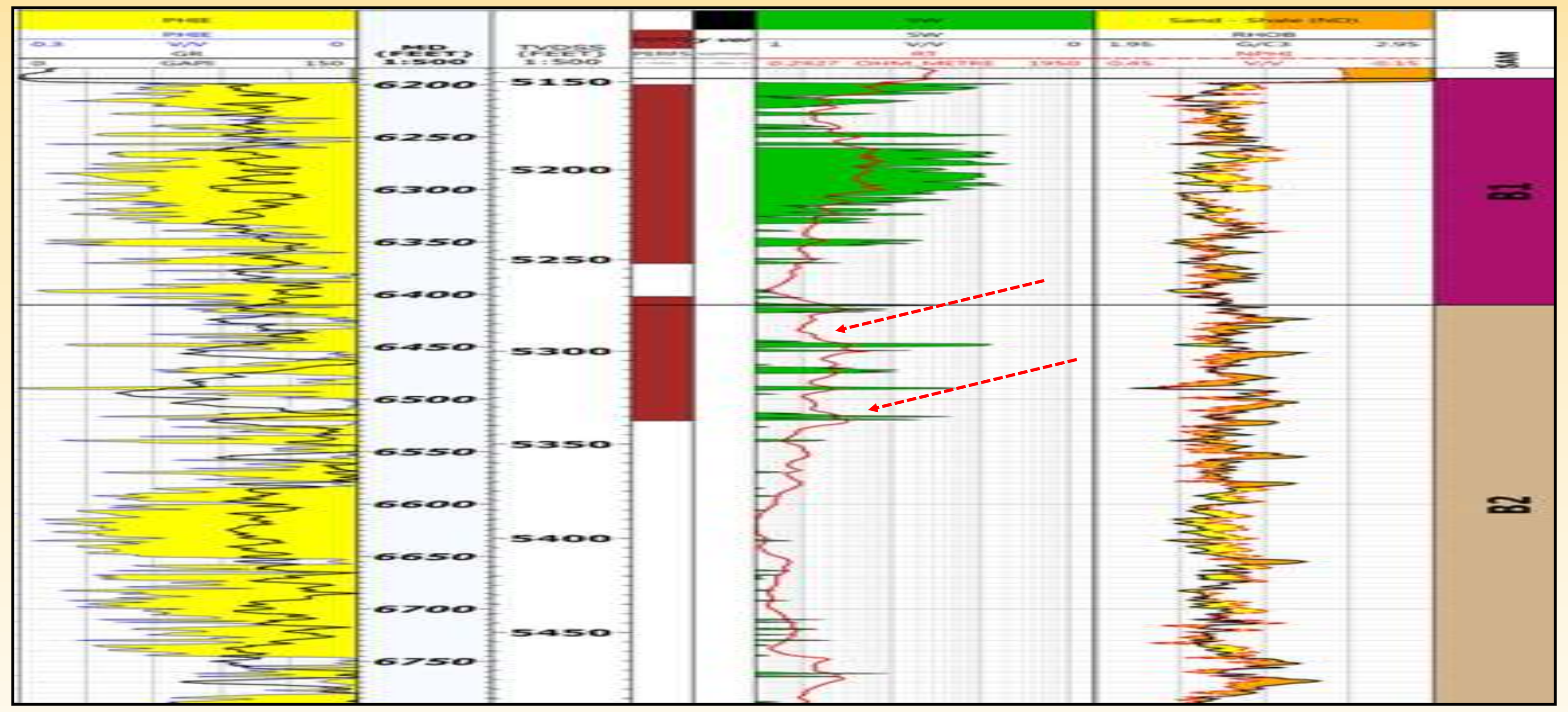
- Good matching between core & processed; porosity and water saturation in addition to the predicted permeability using rock typing technique matching with core & Nuclear magnetic resonance (NMR) permeability's.

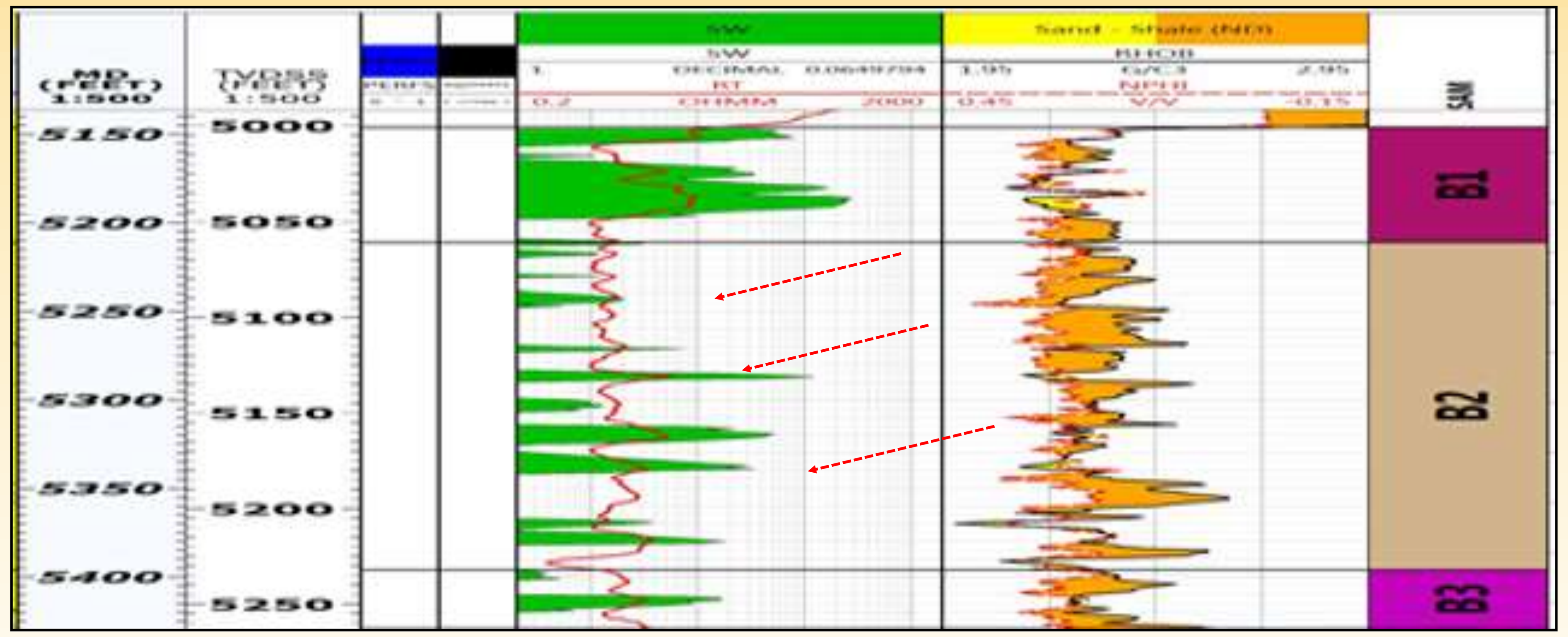
- Hammam Faraun reservoir well test results recovered oil with traces water cut confirmed by production logging tool (PLT) data proved the validity of low resistivity pay concept.

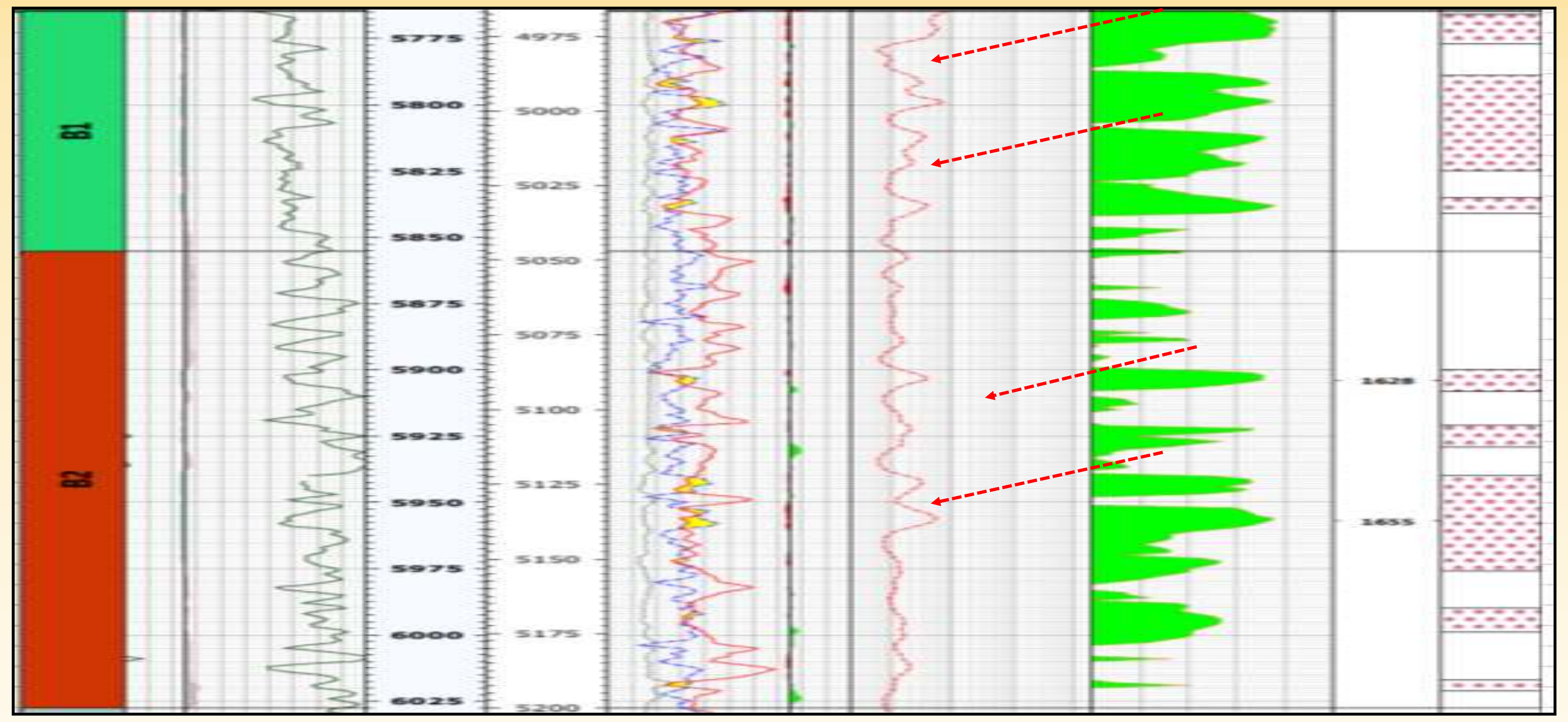
- New development wells are recommended to be drilled in order to increase, enhance the sweep efficiency and recovery factor.

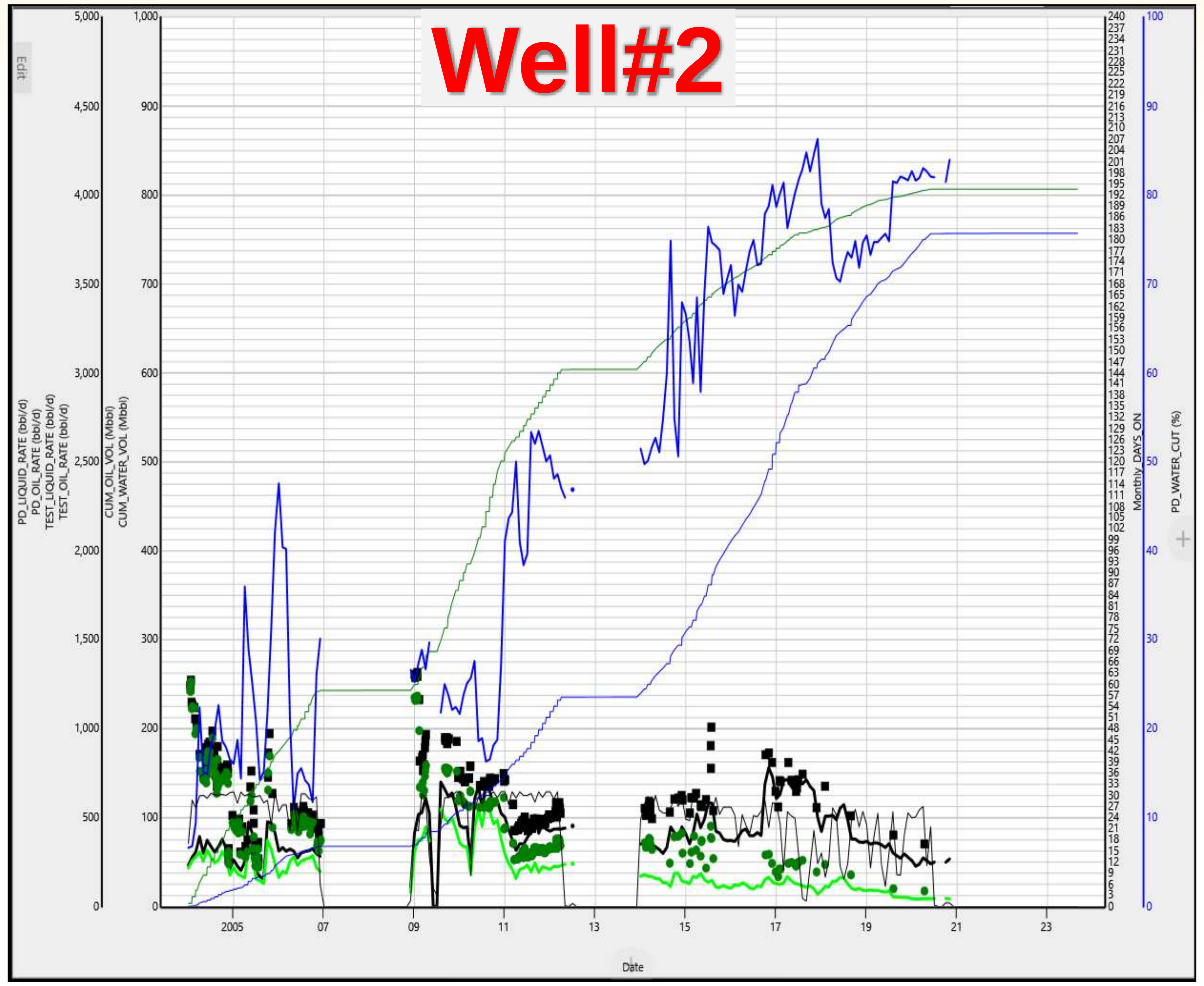
Thank You

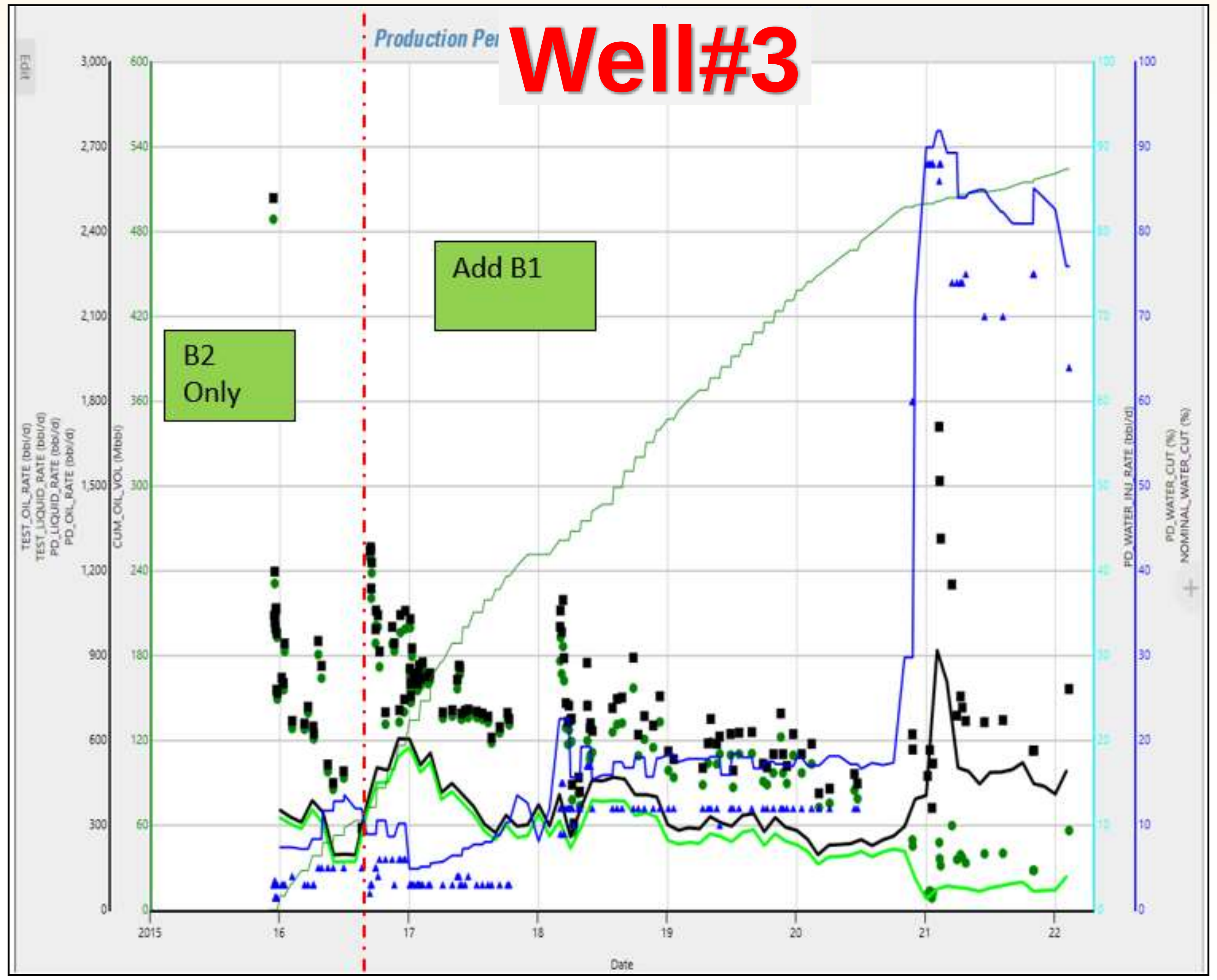
El-Morgan Belayim LRP Performance

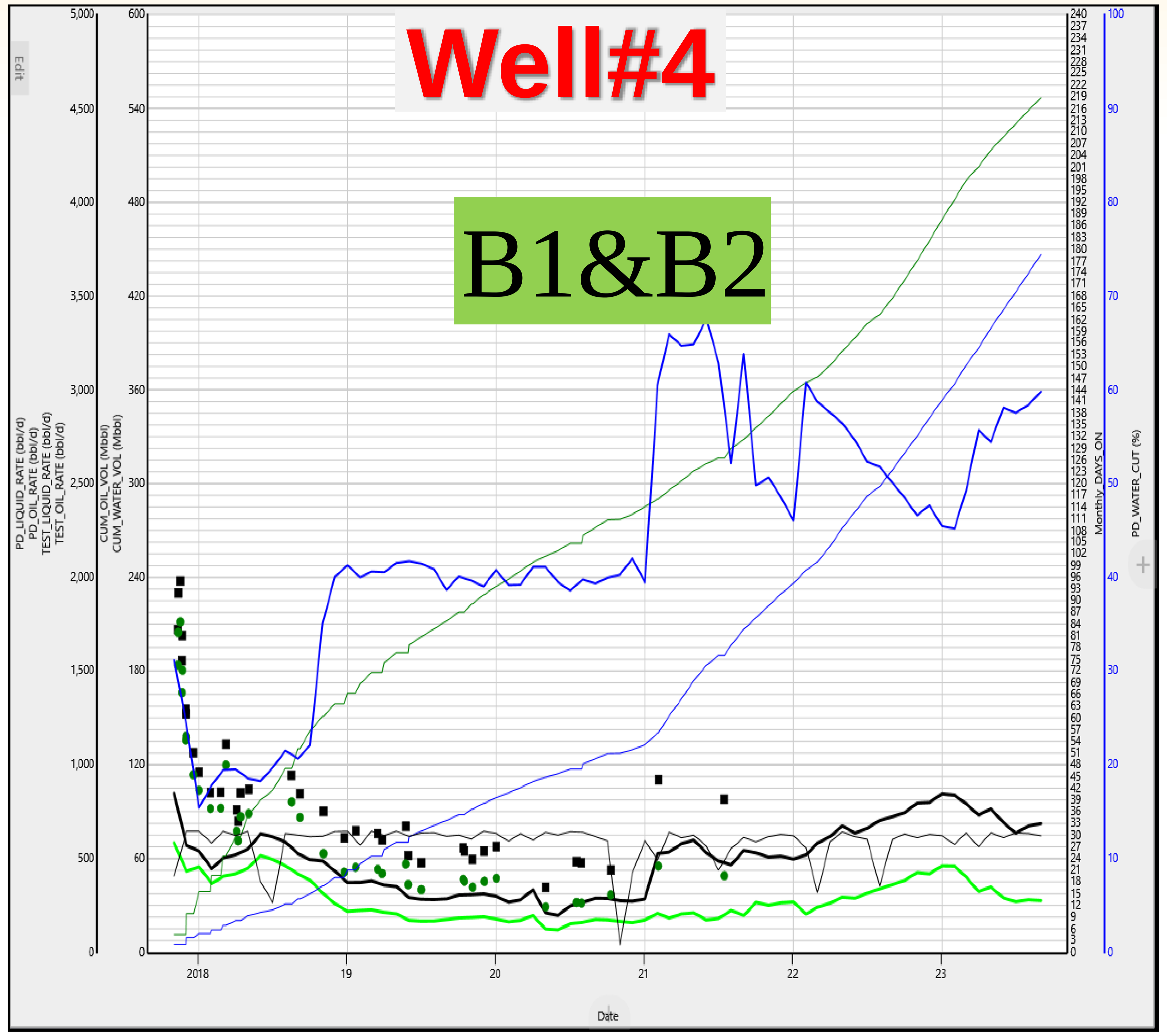












- Well#2 Started with traces WC% commingled in B1&B2.
- The well showed a stable performance.

- Well#3 Started with traces WC% in B2 then when perforated in B1 showed traces WC% as well.
- The well showed a stable performance

- Well#4 Started with traces WC% commingled in B1&B2.
- The well showed a stable performance