An Integrated Approach to Unlock Low Resistivity Carbonate Reservoir in North of Sultanate of Oman*

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Abstract

Predicting productivity and recovery in such a setting as the Natih E Formation requires good understanding and representation of permeability distribution at all scales. An integrated approach is therefore crucial for reservoir description, simulation and forecasting of reservoir performance to optimize reservoir management. The interpretation of hydrocarbon saturation in carbonate reservoirs is often challenging due to their complex and heterogeneous pore structures. Resistivity logs are the main pay-zone identifiers because of the resistivity contrast between oil and water zones. However, when pay intervals exhibit low resistivities, reassessing these intervals can have significant implication in terms of reserves and field development.

The Natih E reservoir is one of the major carbonate reservoirs in the Sultanate of Oman distinguishing itself by multi-level heterogeneities that can give rise to complex geometries in terms of flow paths, porosity and permeability. The Natih E reservoir in the field under study is divided into three zones. The top zone is characterized by patchy leached fabric with local intense dissolution features, thin and thick nodules surrounded by background microporous matrix, with minor oil stain and minor oil saturation computed from logs. The middle zone is a 2 m thick moderately sorted rudstone with a coarse packstone/grainstone matrix with significant macroporosity, with strong oil staining and high log-derived oil saturation. The top zone measured low resistivity and therefore it was not part of the early development, as production was focused on targeting the middle high saturation zone. However, a decision was taken to test the low resistivity reservoir zone. The test showed very good dry oil production and hence additional data were acquired to better understand the complexity of the reservoir. The additional data acquisition included core, NMR and BHI logs, and pressure and downhole fluid identification measurements. The core data gave useful insights about dissolution features, pore structure and facies that impacted the resistivity log. NMR data resulted in a better understanding of the matrix pore size distribution and porosity validation. Downhole fluid samples proved the presence of hydrocarbon in the Low Resistivity Pay interval. This article presents a case study in low resistivity pay in carbonate reservoirs, where the integration of all data sources in a multidisciplinary effort unlocked additional reserves and production from the field.

An Integrated Approach to Unlock Low Resistivity Carbonate Reservoir in North of Sultanate of Oman

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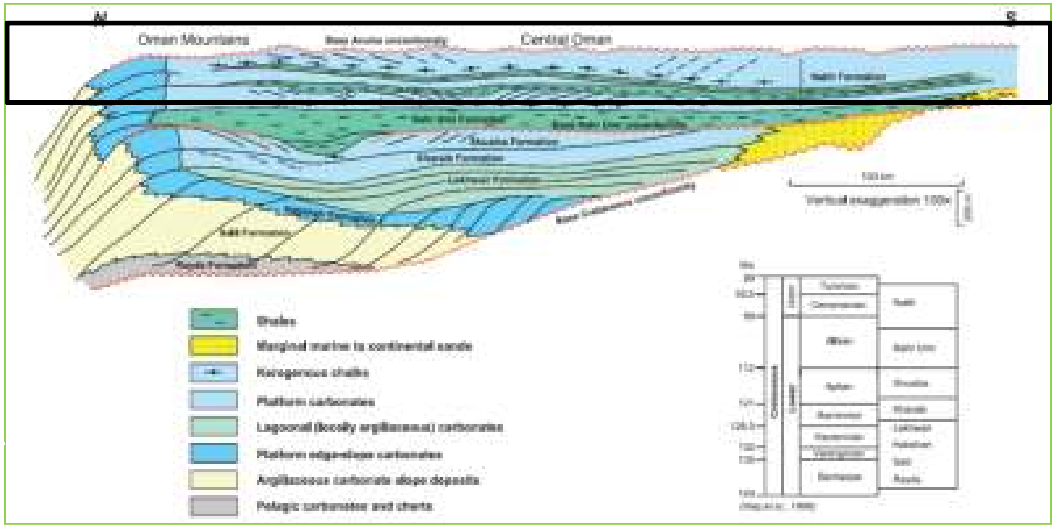
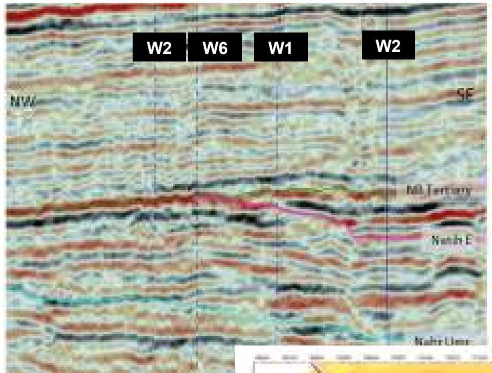
- General Overview Natih Play
- How the logs looks like: compatibility with scale of measurements (micro & meso scale)
- Core understanding
- How Permeability play a significant role
- Conclusions

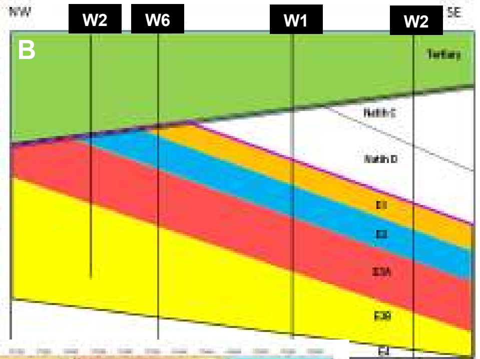
General Overview

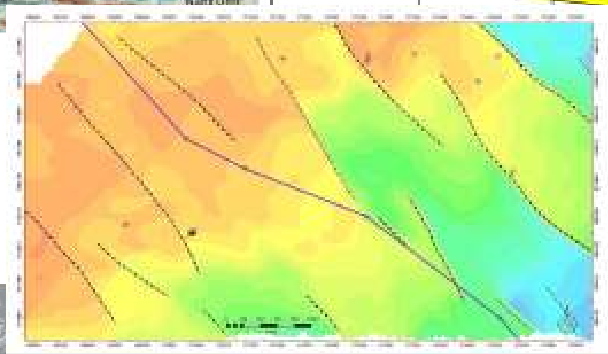
The Natih carbonates were deposited in a ~1000 km wide Cenomanian-Turonian shallow water extensive platform.

Consists of repetitive sedimentary cycles used to subdivide it into seven members from top to base, each representing a sedimentary, generally shallowing upwards, cycle



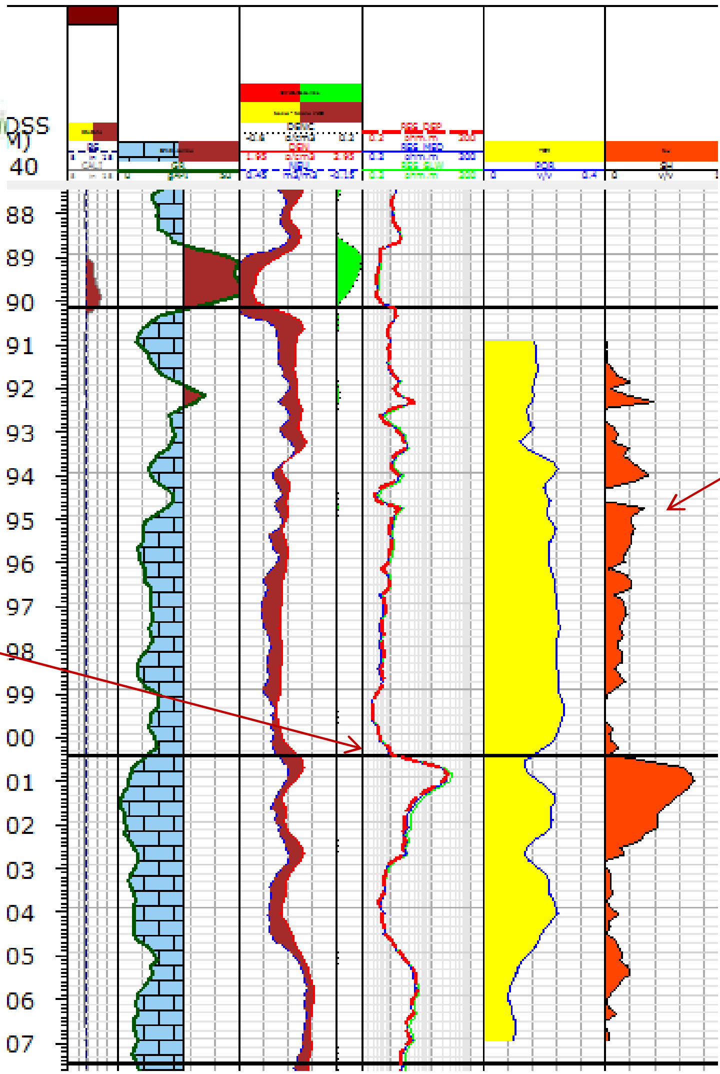






- Stratigraphic & Structural Trap
- Fracture Reservoir
- Porosity 19-24%
- Poro /Perm strongly influenced by depositional setting.
- Multi Darcy Permeability 0.1mD up to ~8D
- Medium light oil 26 API
- Low GOR
- H2S concentration high up to 100 to 400ppm (gas phase)

Log type



Middle zone

- Rudstone with coarse packstone/Grainstone matrix with significant macroporosity, with strong oil staining.
- Lowest resistivity also associated with
- High Saturation only in Grainstone, having a signature from logs when above current contact. (~ 3 m)

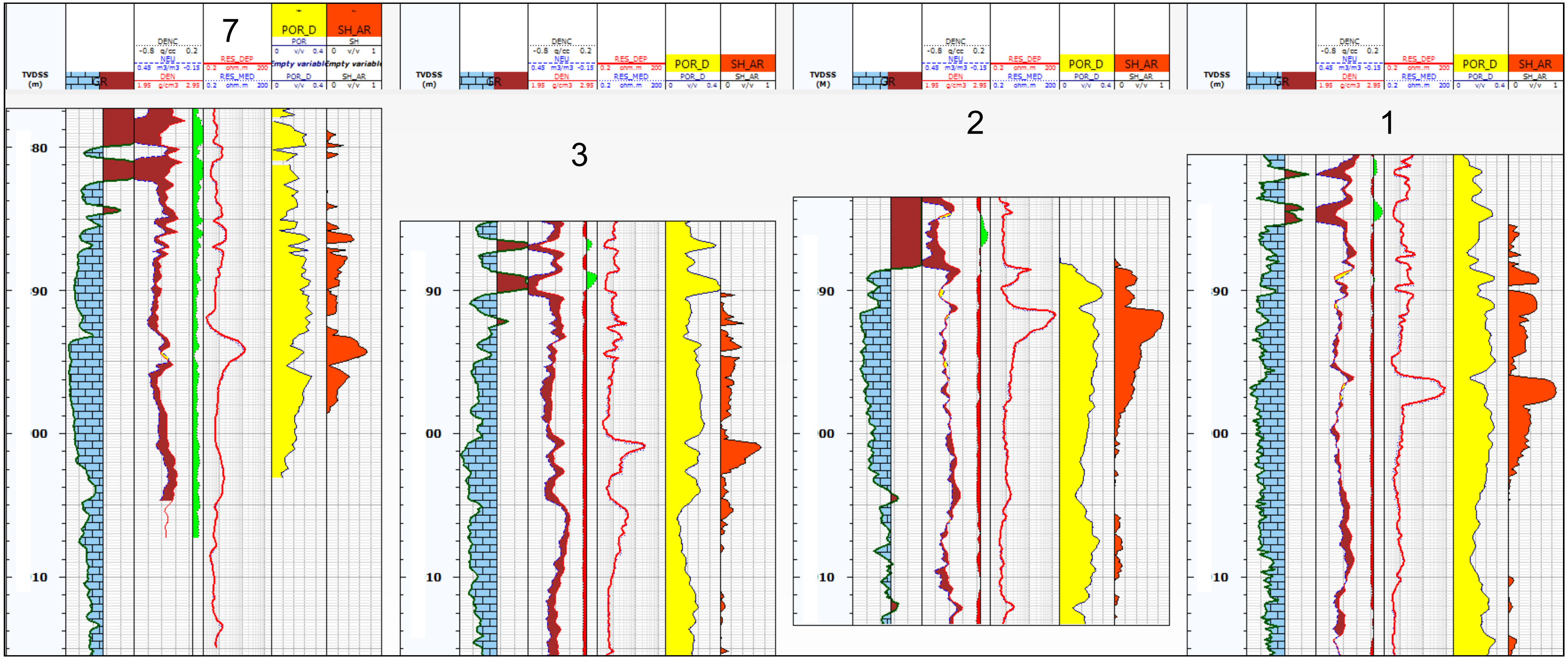
Top Zone

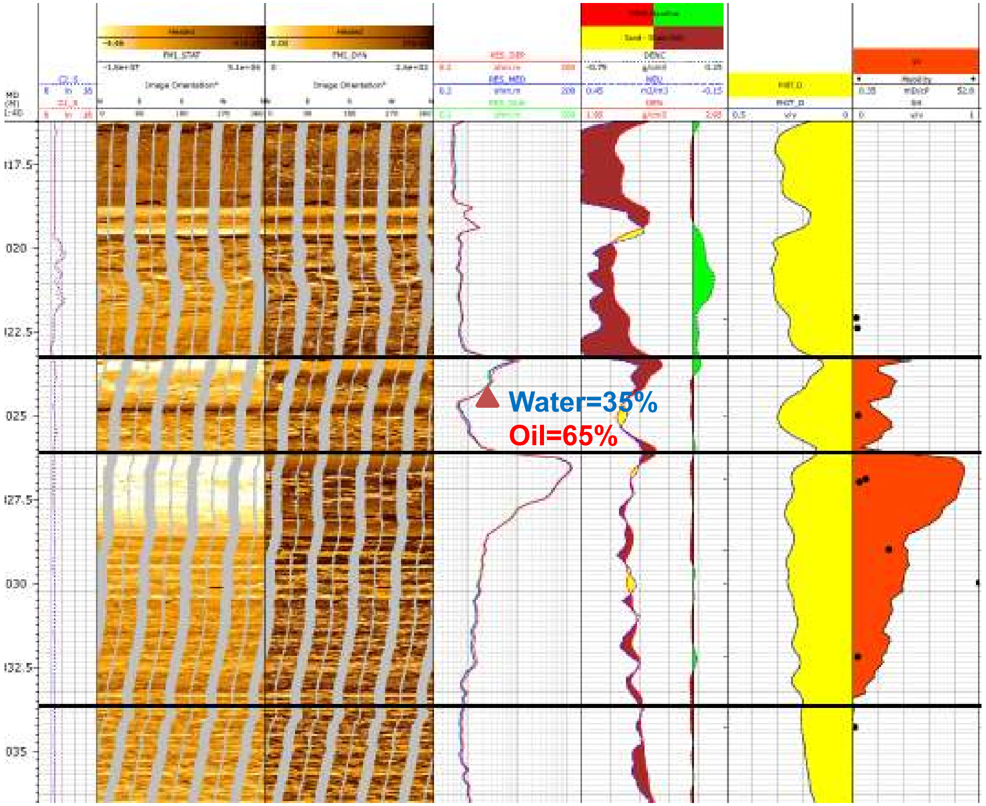
- Characterized by patchy leached fabric with local intense dissolution features,
- Low resistivity could be associated to clay content and microporosity ??

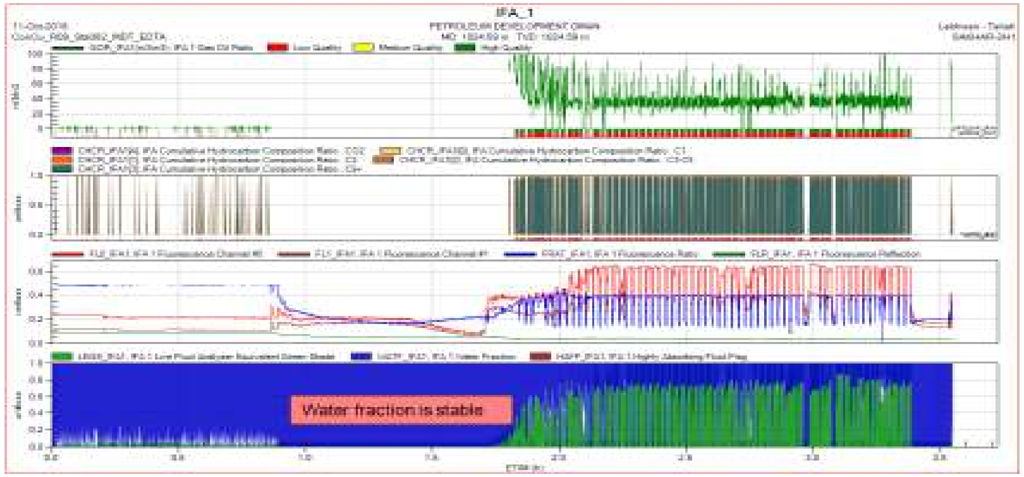
Low zone:

- Microporus pore facies (Layered) below (~ 5m)

Why Low Resistivity in the Top Zone?







Downhole Fluid Identification

Water	C1	C2	C3-C5	C6+	GOR
35%	2%	0%	3%	60%	35-45 m3/m3

Where the production is coming from? Matrix or Fractures or both??

After sampling results well was completed on a 2m top (Top Zone).

W2	Initial Production
Avg Oil Rate, m3/d	80
Water Cut, %	20%
Avg Liquid Rate, m3/d	100

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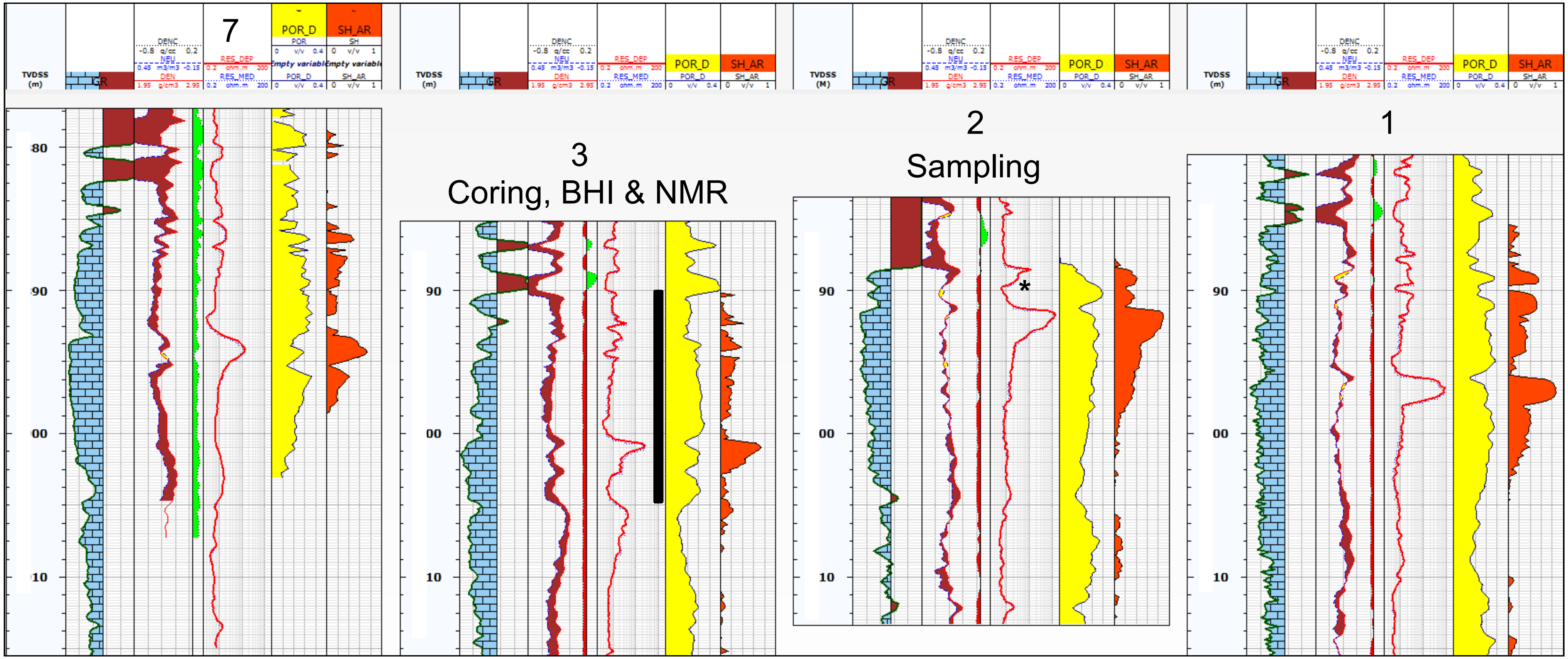
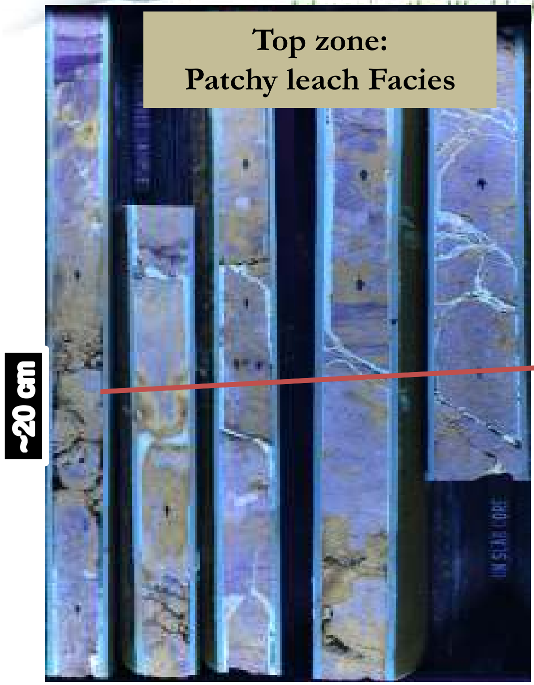
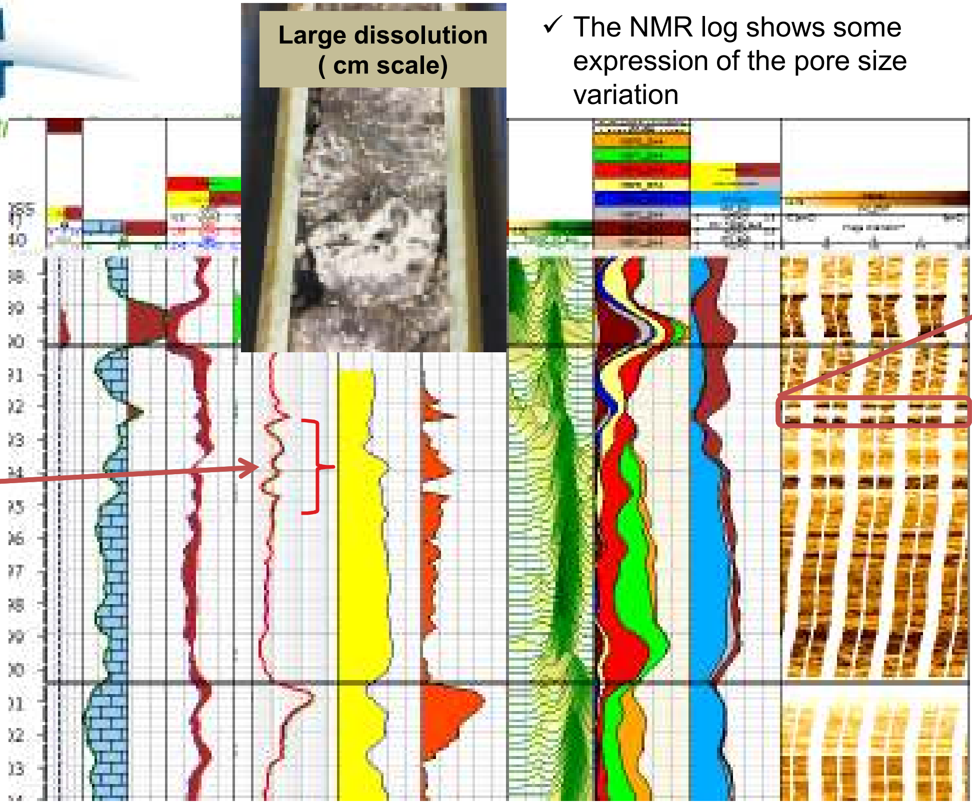
Why Low Resistivity in the Top Zone?



Well 3 (Core)

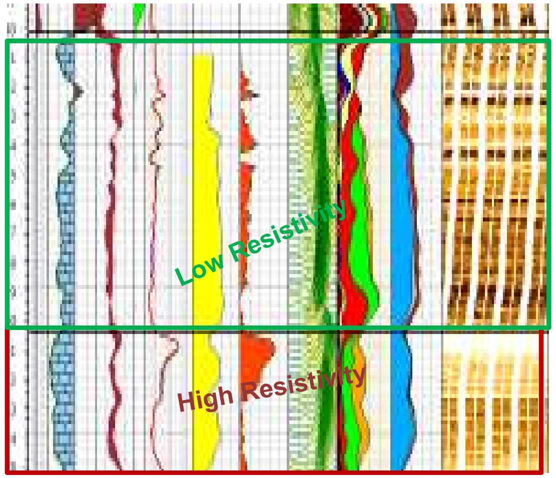




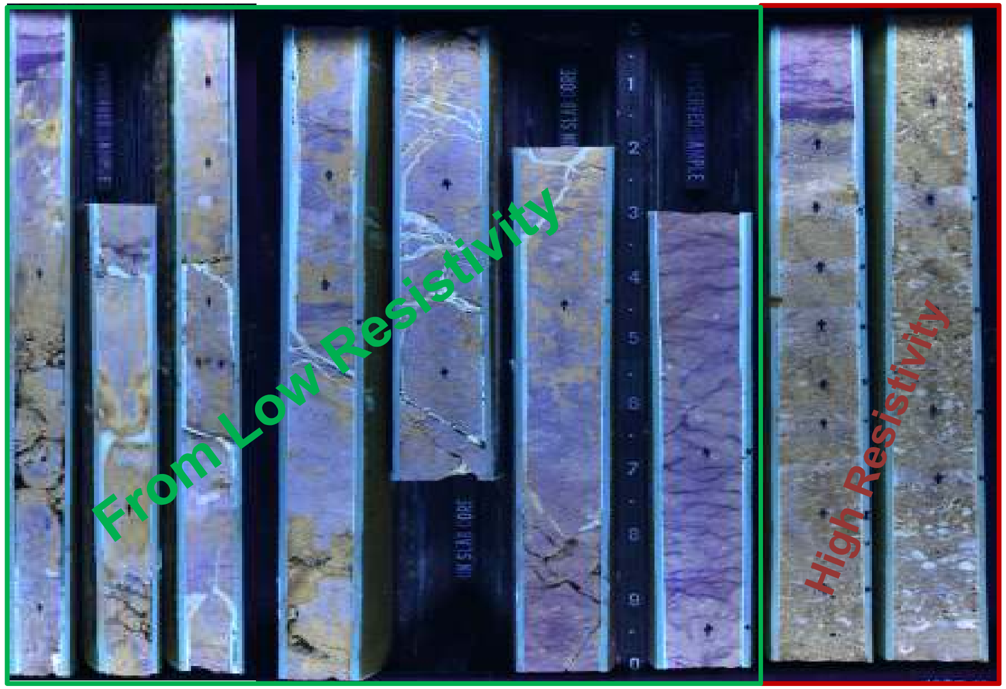
- ✓ The NMR log shows some expression of the pore size variation

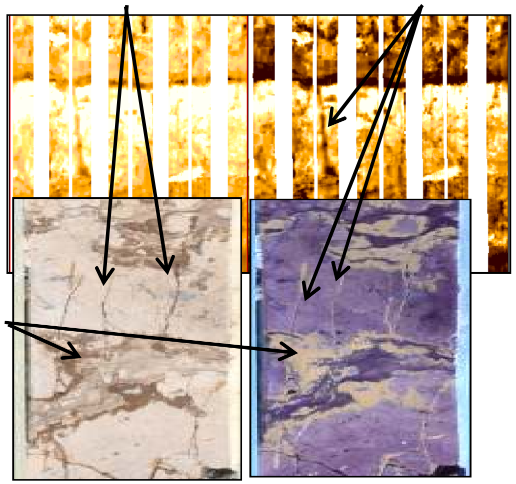
- ✓ Patchy leach Fabric with local intense dissolution features; thin and thick nodules surrounded by thin and thick Rims embedded in Matrix.
- ✓ Vertical resolution of Resistivity log can not solve for high resistivity nodule and Medium Resistivity Matrix. (less than 20 cm)
- ✓ The size of measurement of core plug (1 – 2in.) is much smaller than a well test drainage radius (10’s – 100’s m).

Low Resistivity contrast



Open pore systems along which oil has migrated into/along microfractures, the small voids and into grain-filled patches.

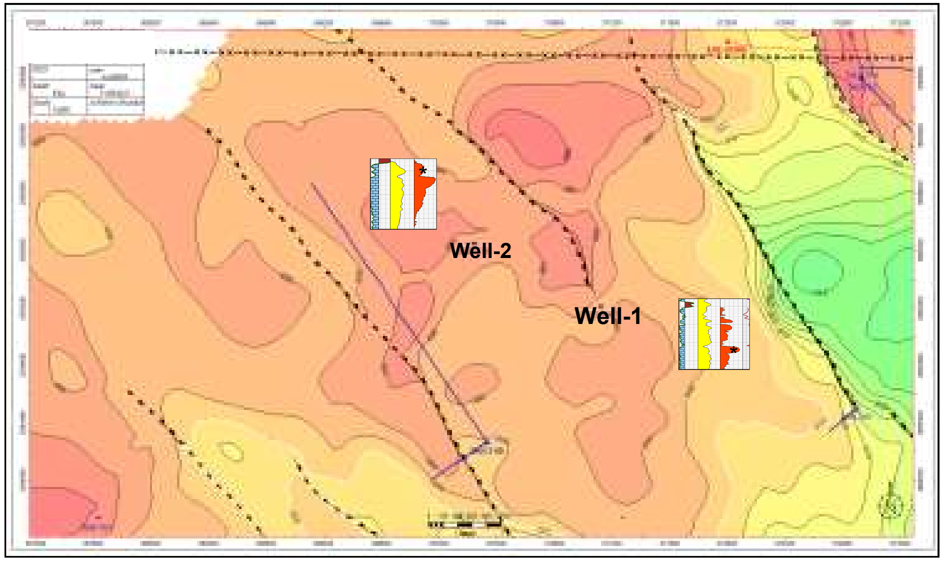


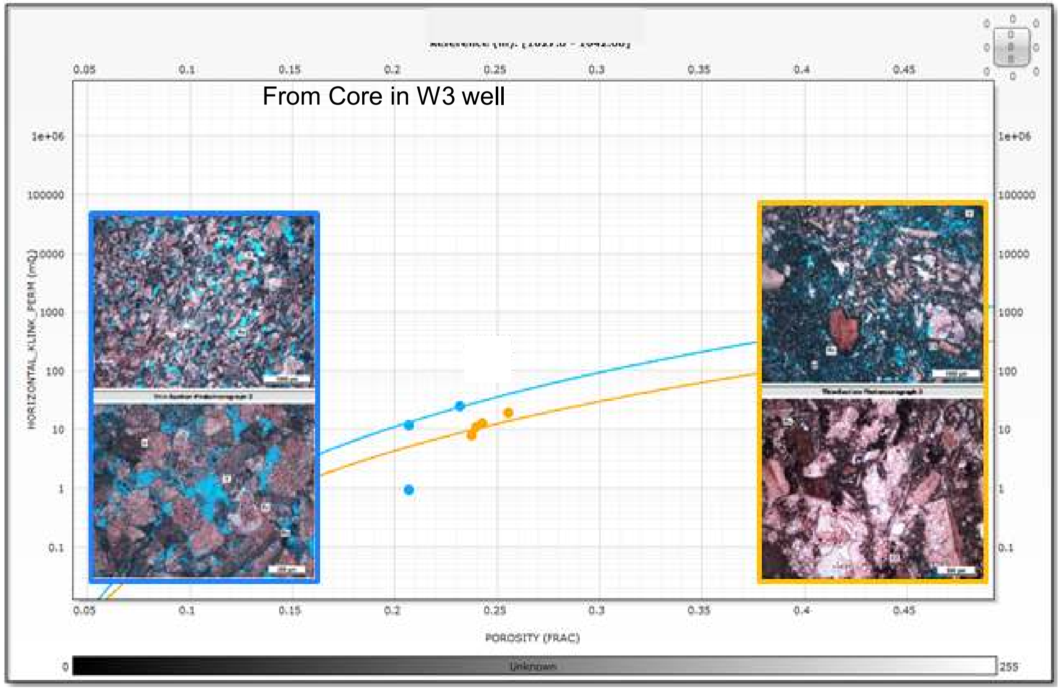


The fractures are clearly visible.
The open Veins/microfracture clearly post-date the early diagenetic fabrics;

Locally patchy oil stain.
Microfractures appear to connect some patches.

BUT in W2 well





Source of Measurement	Core k (md)	Build up test k (md)	MDT Mobility md/cp
Top Zone	Max ~22	~1600	Max 15

The patchily distributed micropores control the pore connectivity and result in the <u>poor measured permeability value</u>. Small amounts of porosity within the fracture may improve connectivity at the core-scale

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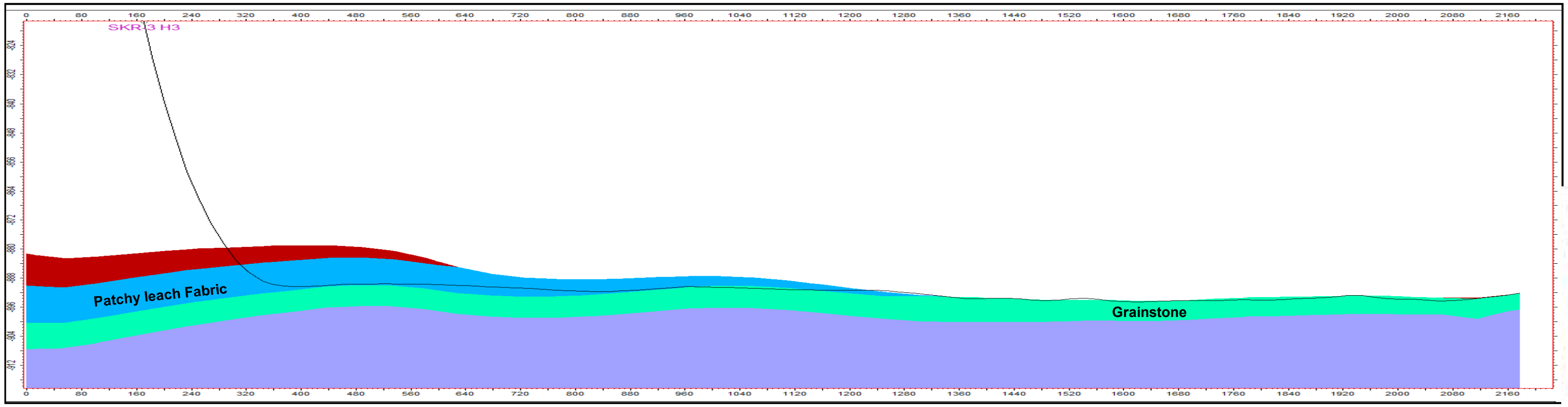

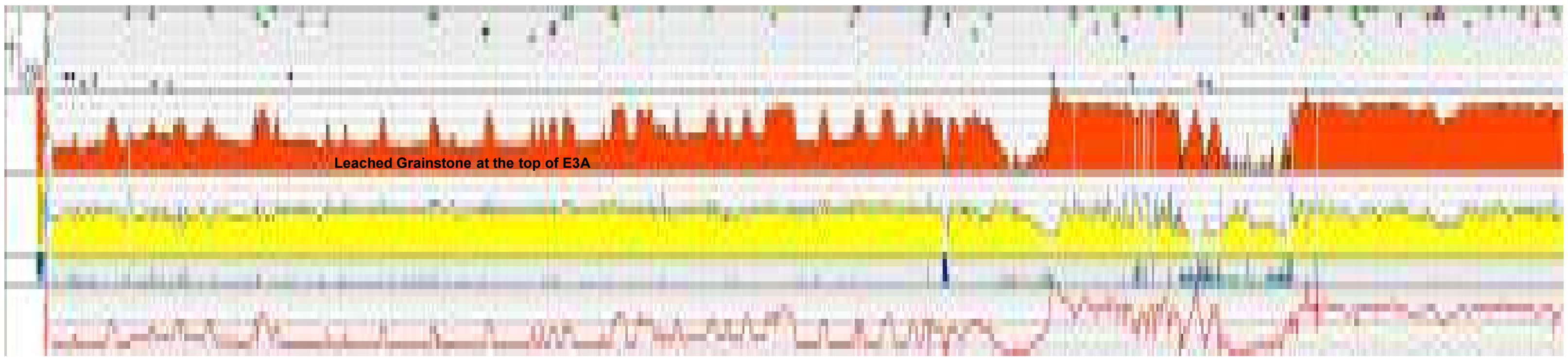

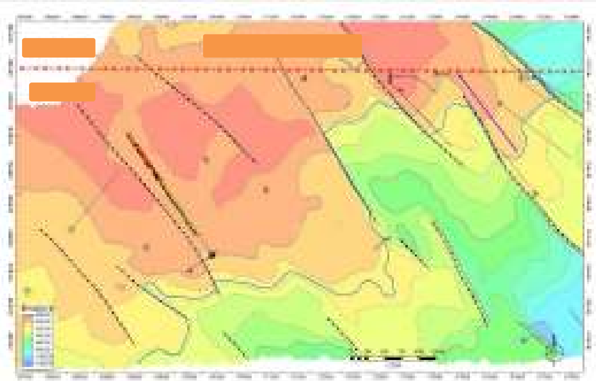

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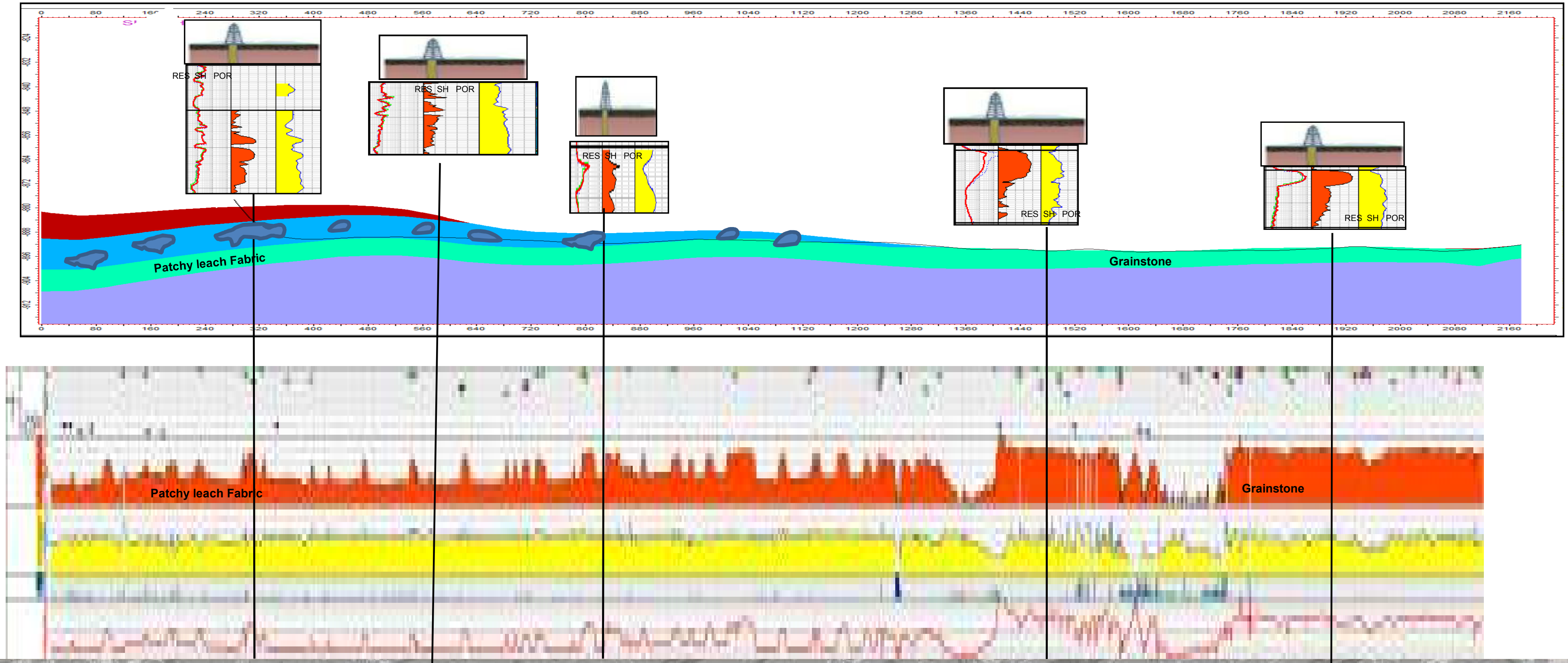

Conclusions

- Matrix and fracture permeability heterogeneities are key factors in explaining reservoir performance and production.
- The core data gave useful insights about dissolution features, pore structure and facies that impacted the resistivity log.
- NMR data resulted in a better understanding of the matrix pore size distribution and porosity validation
- Downhole fluid samples proved the presence of hydrocarbon in the Low Resistivity Pay interval.
- From BHI in a horizontal it was observed that the well trajectory intersected series of fractures and the patchily distributed micropores control the pore connectivity.