

# **Petrophysical Characterization of Carbonates of Campos Basin in Southeastern Brazil\***

**Antonio Carrasquilla<sup>1</sup>**

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## **Abstract**

In our studies, we analyzed geological, geophysical, and petrophysical data sets (DS) from different wells and in oil fields of Campos Basin, Southeastern Brazil, to assess the carbonate reservoirs' physical properties. Beside this, we examine the ability of artificial intelligence techniques (AIT) in deriving petrophysical parameters as porosity and permeability of these reservoirs starting from conventional logs. The purpose of these studies is to test our hypothesis that it is possible to achieve a more accurate profile of the distribution of the properties of reservoirs through a qualitative and quantitative analysis of integrated DS and AIT. Our results show that the integration of both DS and AIT to greatly enhance the petrophysical evaluation, indicating that the studies in reference wells can be extended to the rest of the wells of the oil fields, to have a more complete view of the carbonate reservoirs.

## **References Cited**

Gaglowiccz, A., 1983, Vers un Modele de Textures: Springer-Verlag, 351 p.

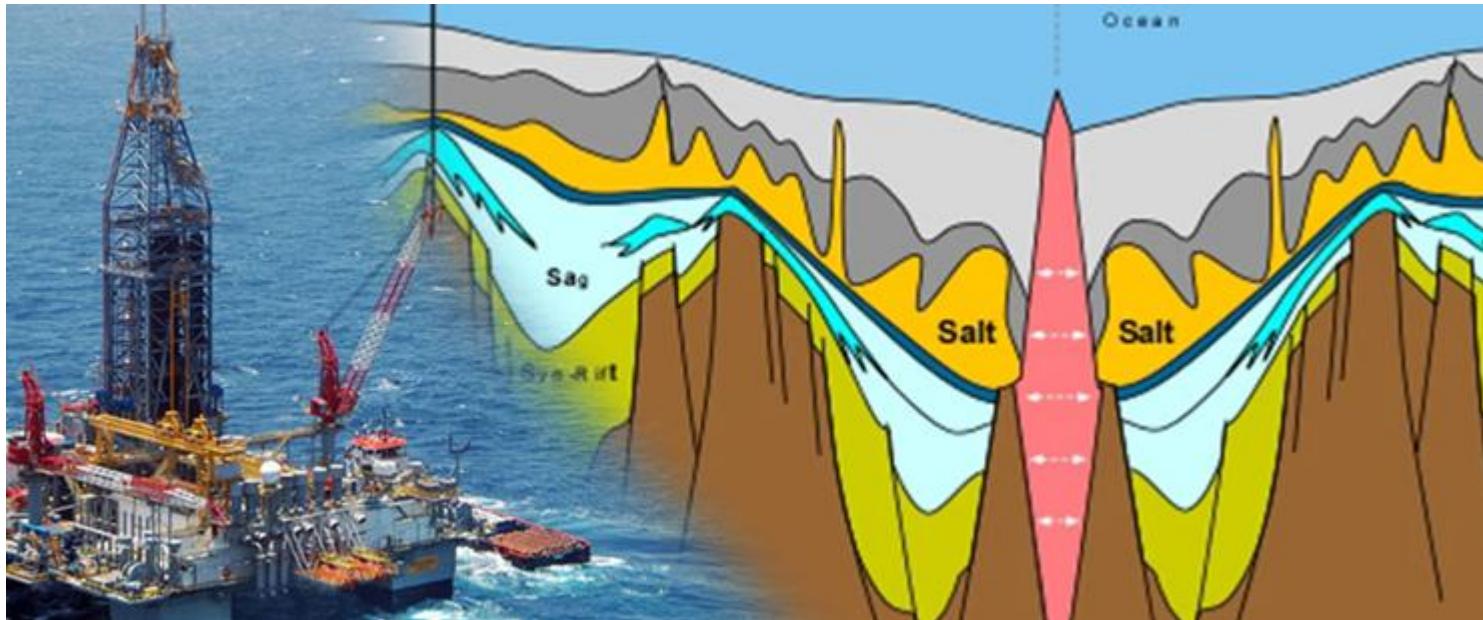
Rabiller, P., J. Etrillard, L. Toupet, J.M. Kiat, P. Launois, V. Petricek, and T. Breczewski, 2001, Disorder versus structure analysis in intergrowth urea inclusion compounds: Journal of Physics: Condensed Matter., v. 13, p. 1653-1668.

# WORKSHOPS

A joint AAPG-EAGE Geoscience Technology Workshop

## Carbonate Plays Around the World – Analogues to Support Exploration and Development

4-5 February 2015 | New Orleans, Louisiana, United States



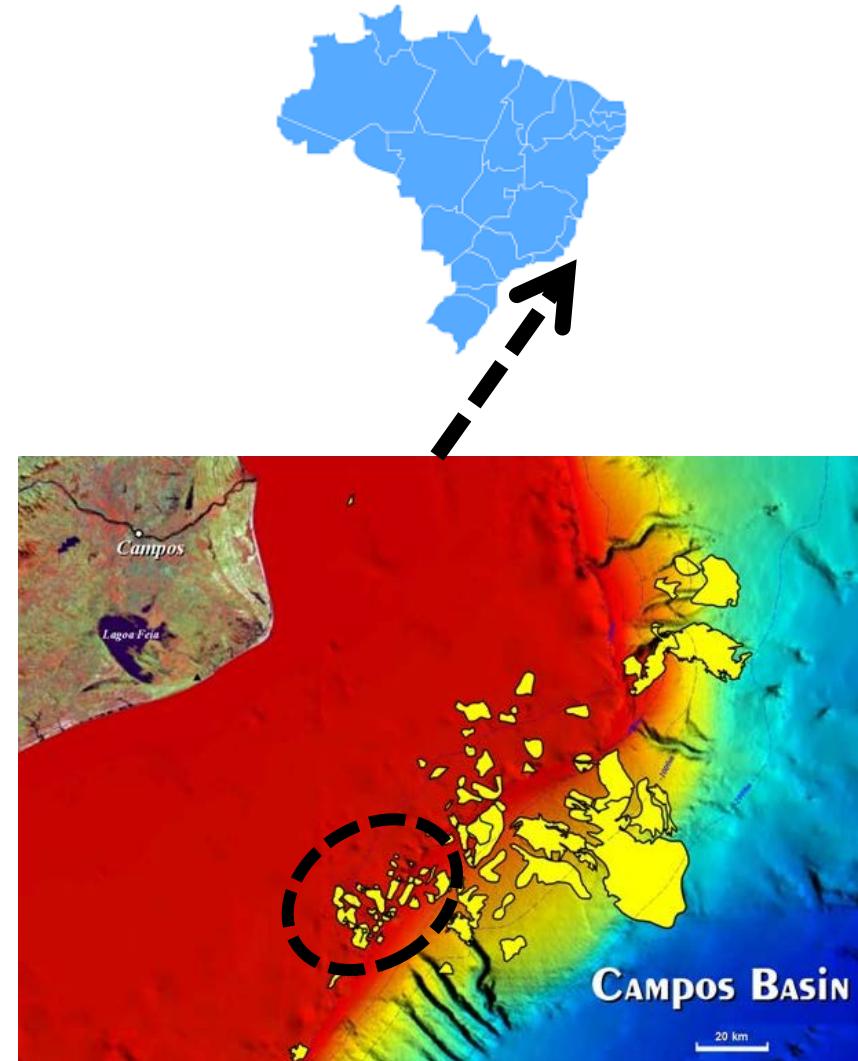
### Petrophysical Characterization of Carbonates of Campos Basin in Southeastern Brazil

*Prof. Antonio Abel González Carrasquilla*

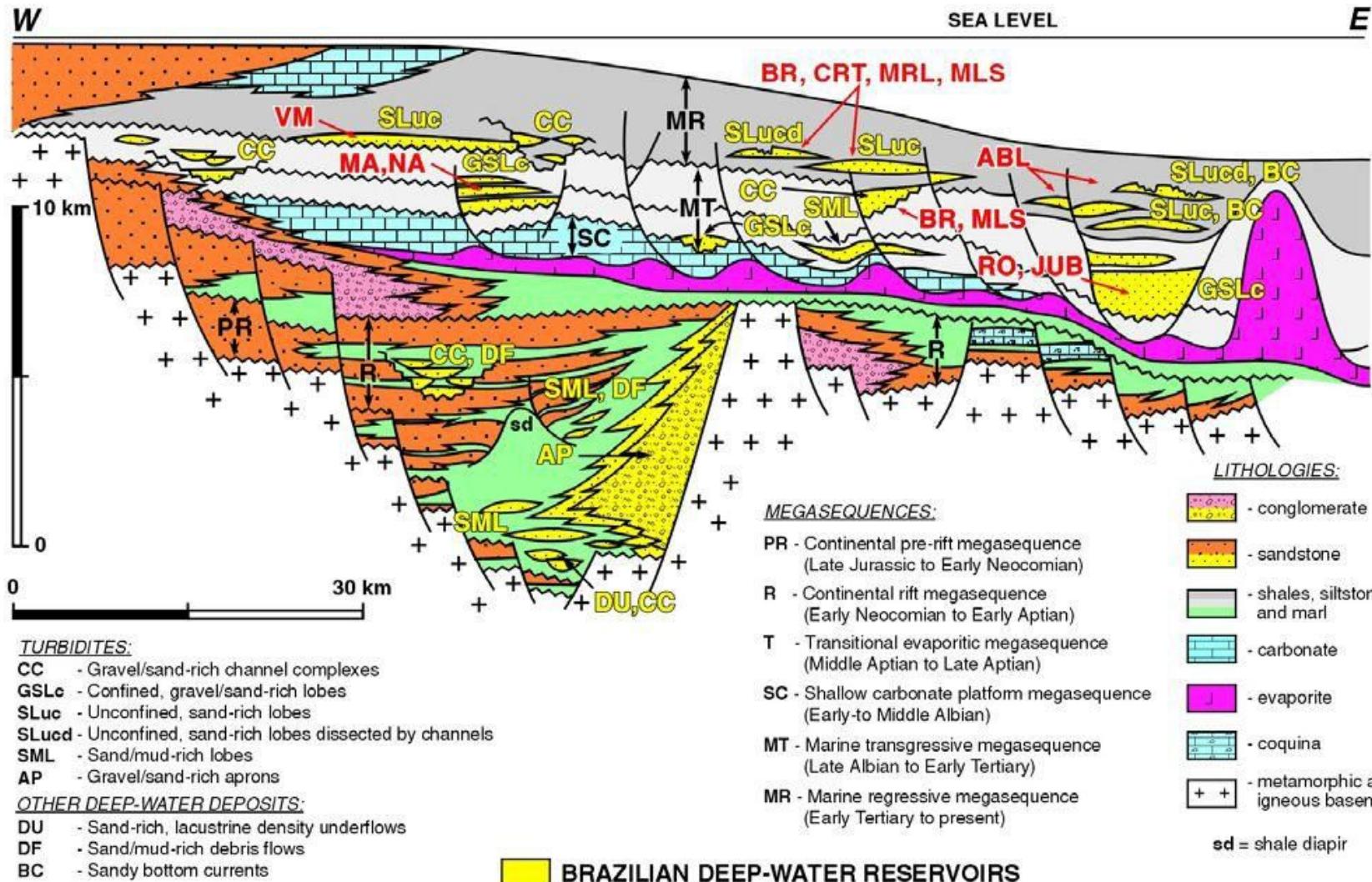
Northern Rio de Janeiro State University Darcy Ribeiro / UENF  
Petroleum Exploration and Engineering Department  
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# Outline

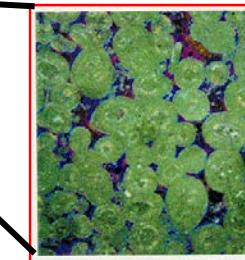
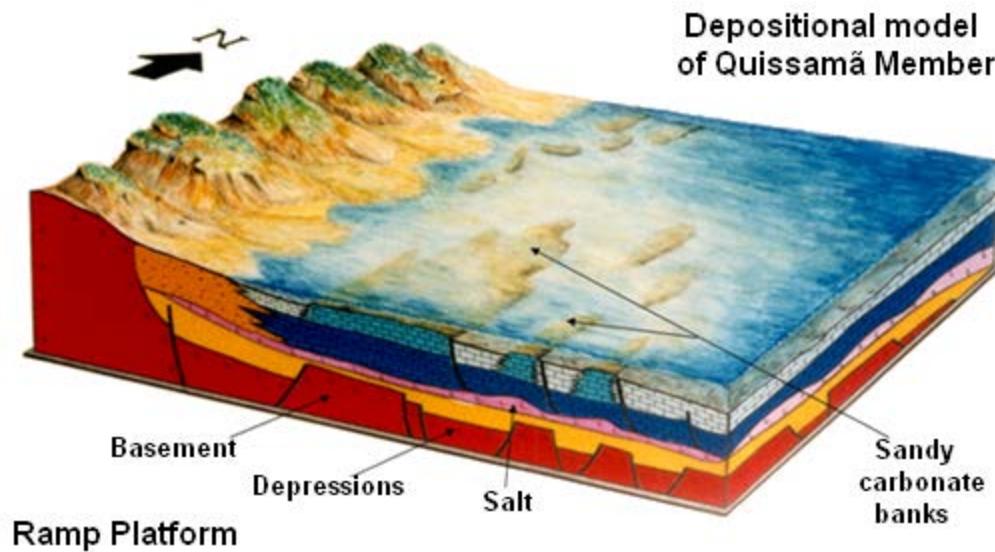
- Introduction
- Geological context
- Available information
  - 1<sup>st</sup> oilfield
  - 2<sup>nd</sup> oilfield
- Case studies
  - MSc. thesis - 1<sup>st</sup> oilfield
    - Nocchi
    - Torres
    - Briones
  - Research project - 2<sup>nd</sup> oilfield
- Conclusions
- Acknowledgements



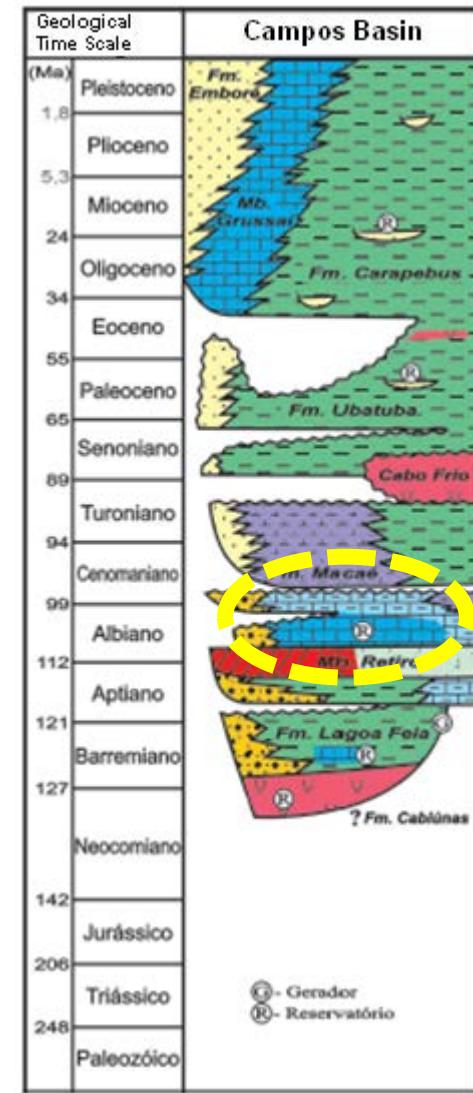
# Post-Salt Carbonates



# Geological context



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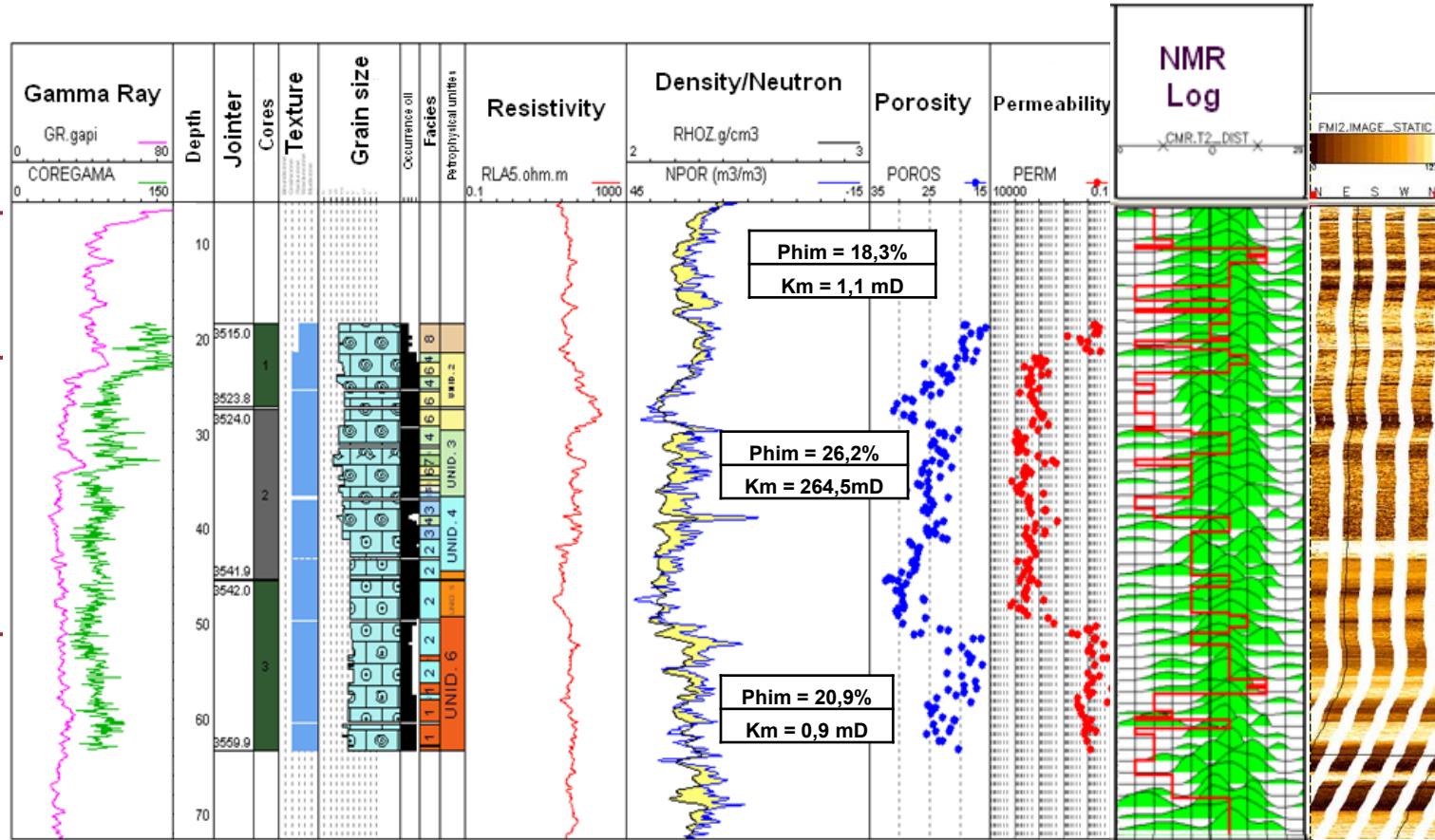


# Available information 1<sup>st</sup> Oilfield (3 wells)

Packstones  
Section

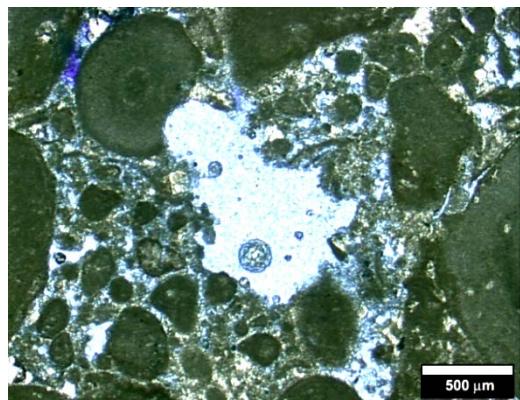
Grainstone  
Section

Cemented  
Section



# Available information 1<sup>st</sup> Oilfield (3 wells)

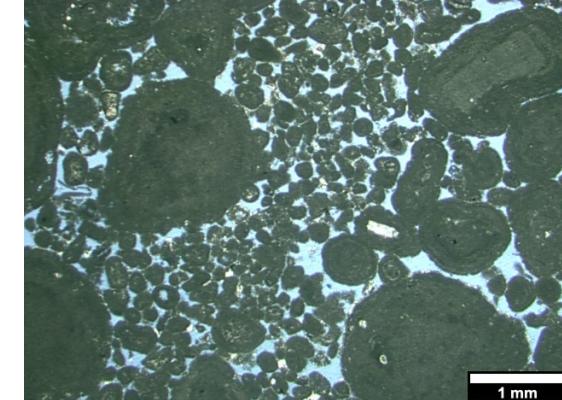
1cm



Oncolitic/peloidal grainstone with intergranular and vugular porosity (25%).



Oolitic grainstone with aggregates. Intergranular porosity (25 - 30%). Presence of open subvertical fractures stained with oil.

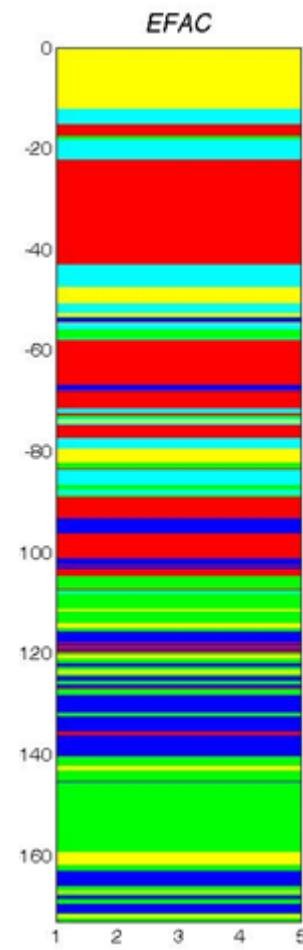
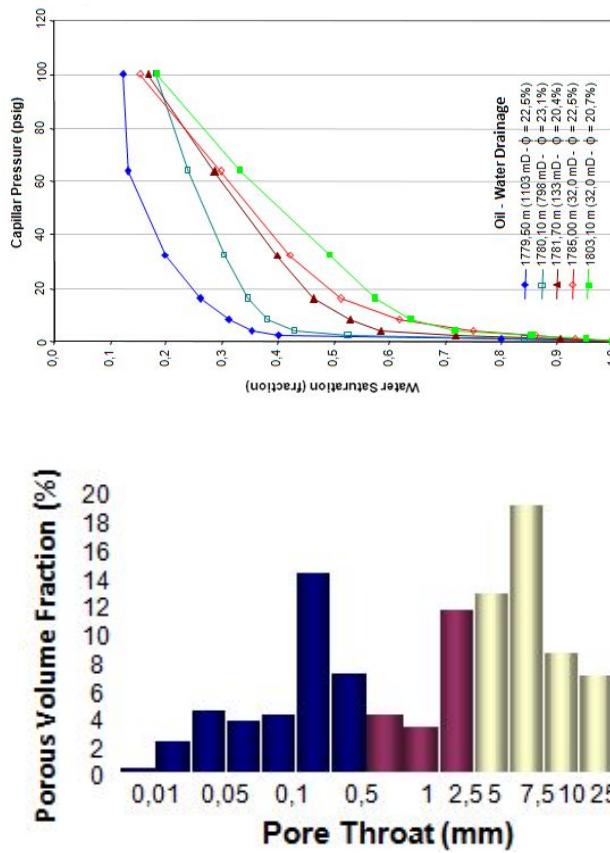
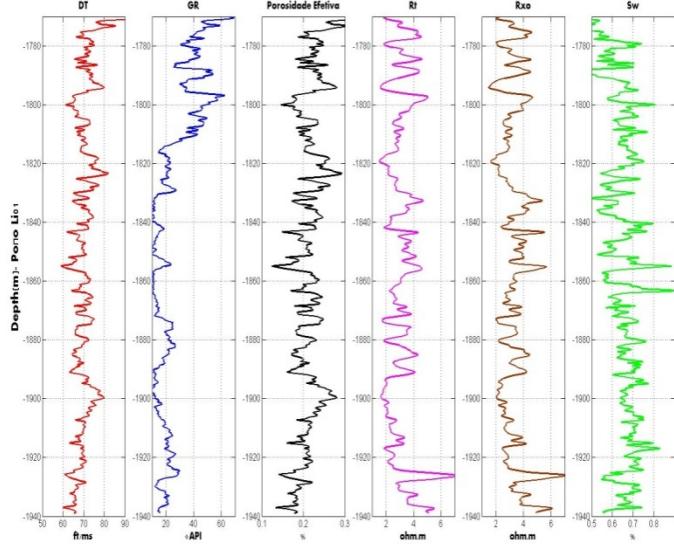


Micro oncilitic/oncilitic grainstone, rare ooliths and peloids. Intergranular and vugular porosity (25%).

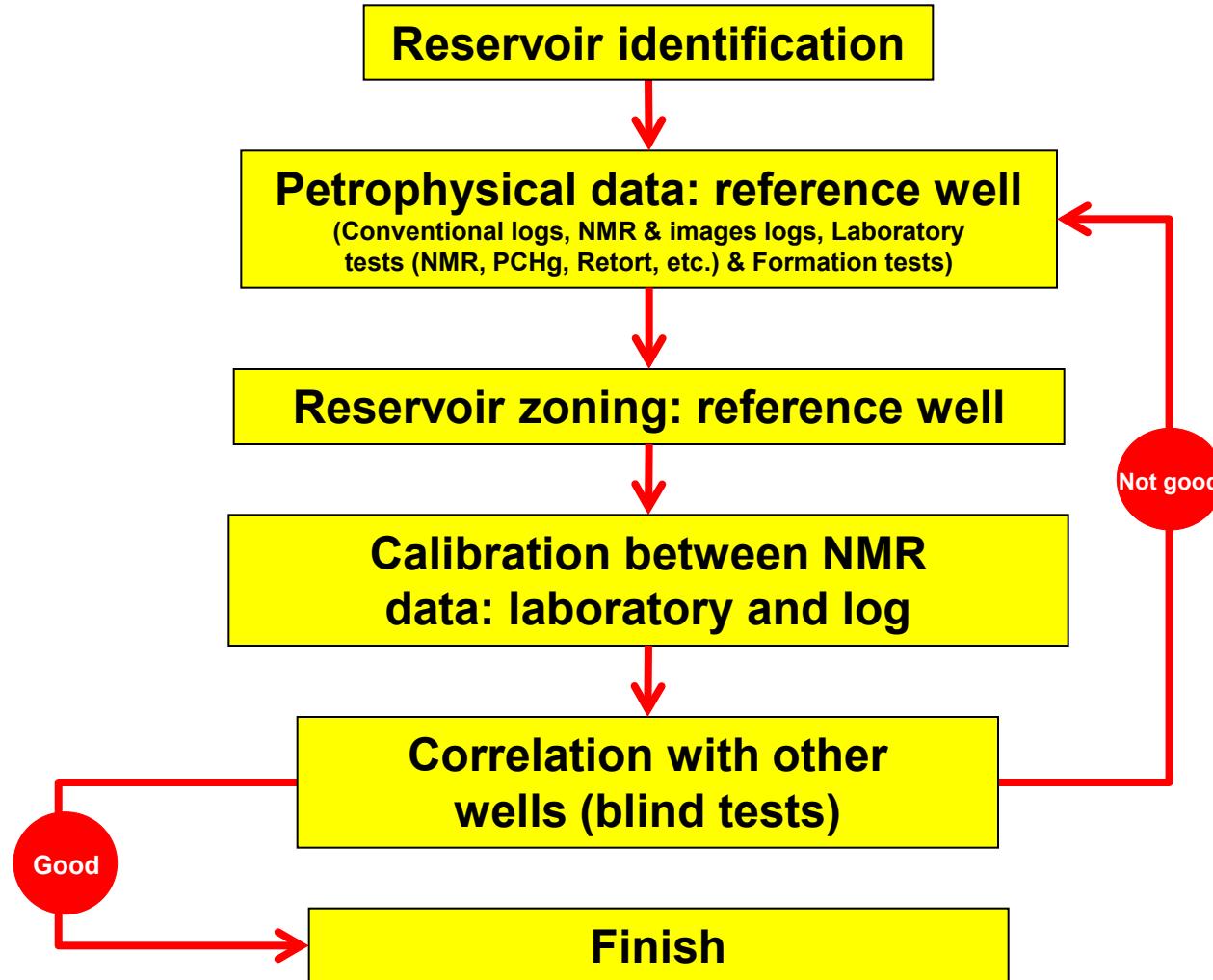
Grainstones Porous oolitic/microoncolitic. Optimal intergranular porosity, partly enlarged by dissolution.

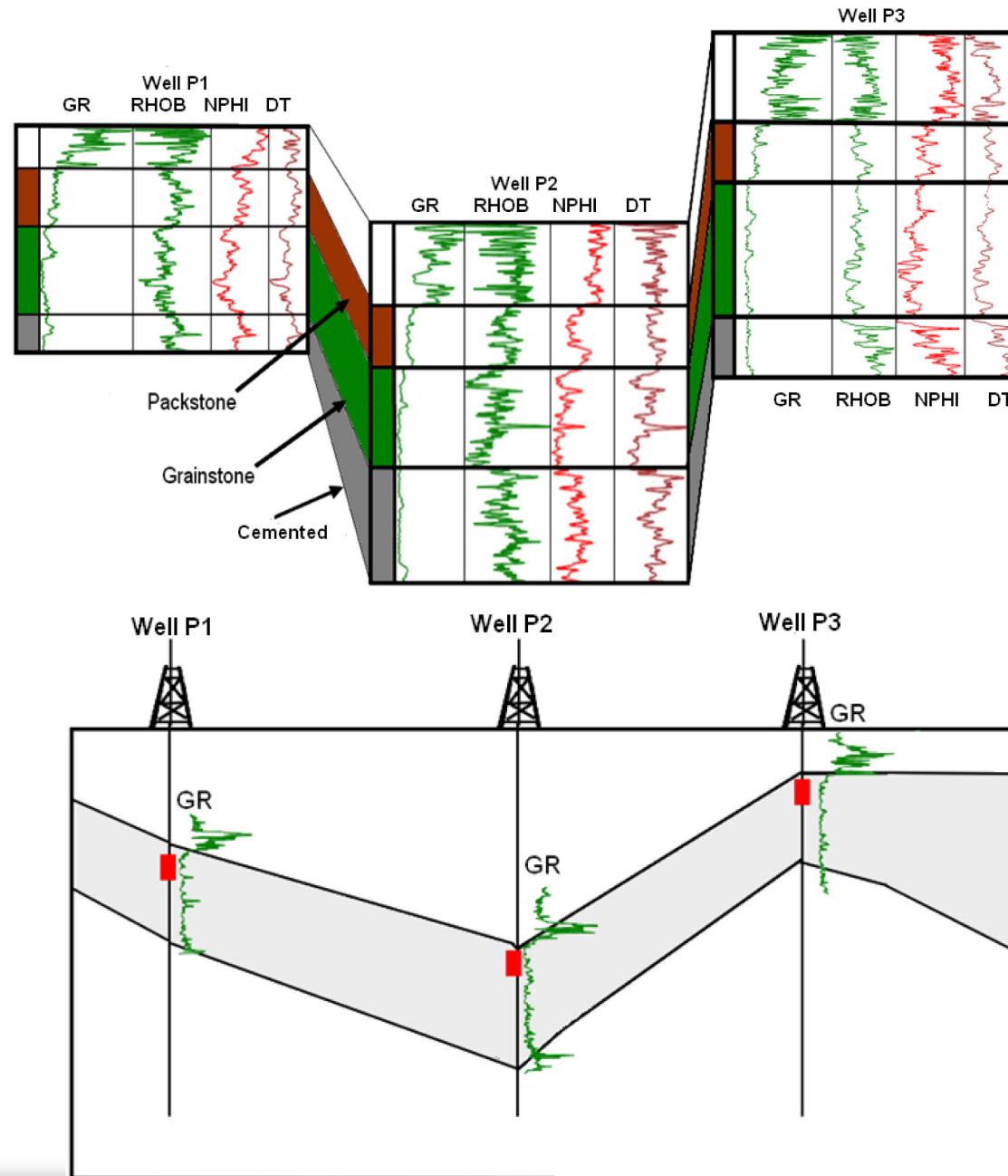
# Available information 2<sup>nd</sup> Oilfield

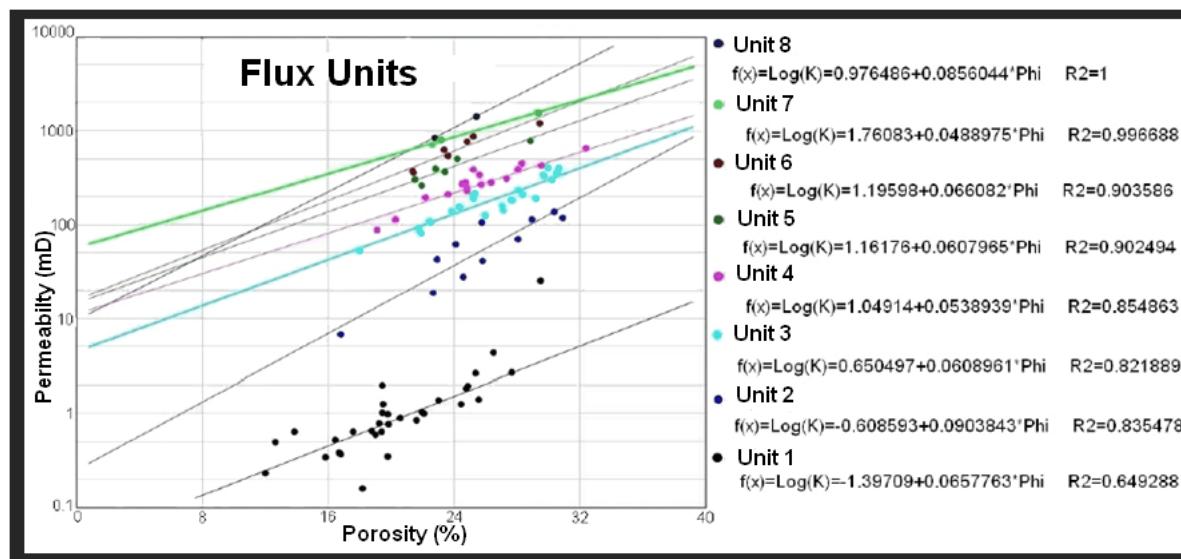
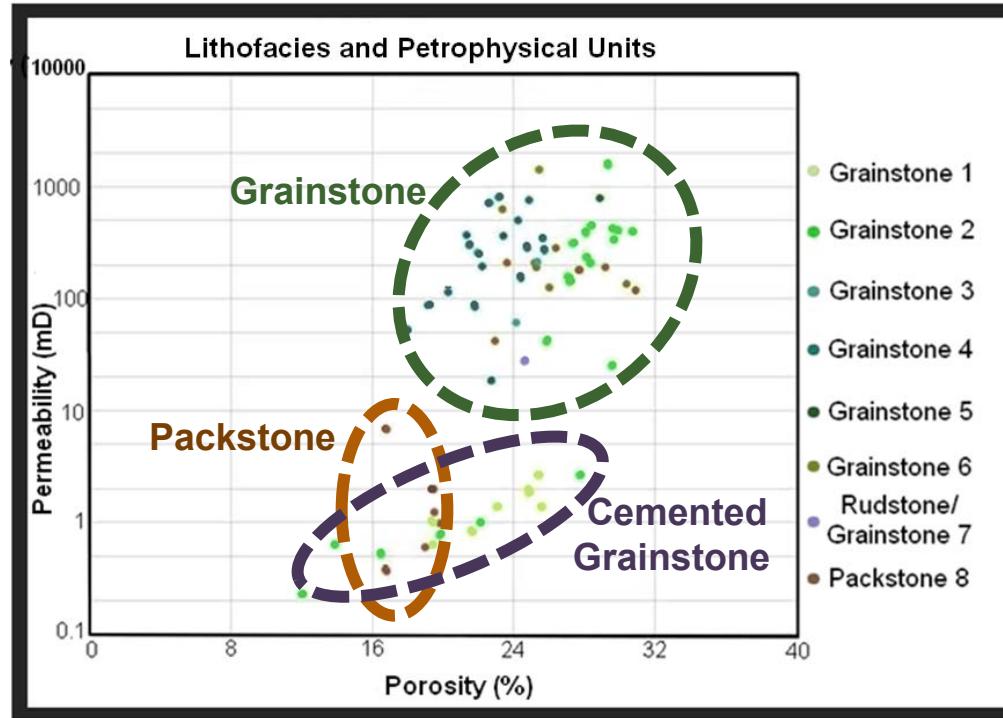
- Well logs of 27 boreholes;
- lithofacies information for all wells;
- basic petrophysics core data for 3 wells.



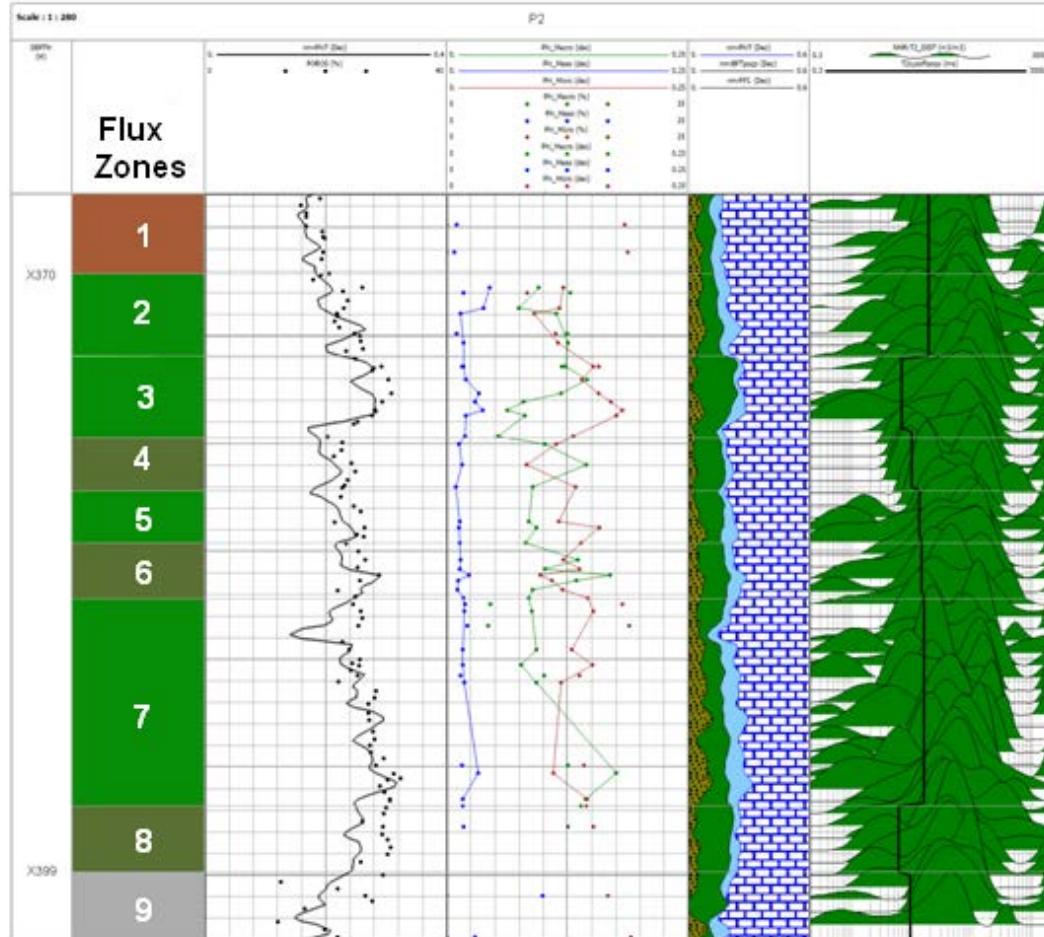
# Work flow 1 - 1<sup>st</sup> oilfield





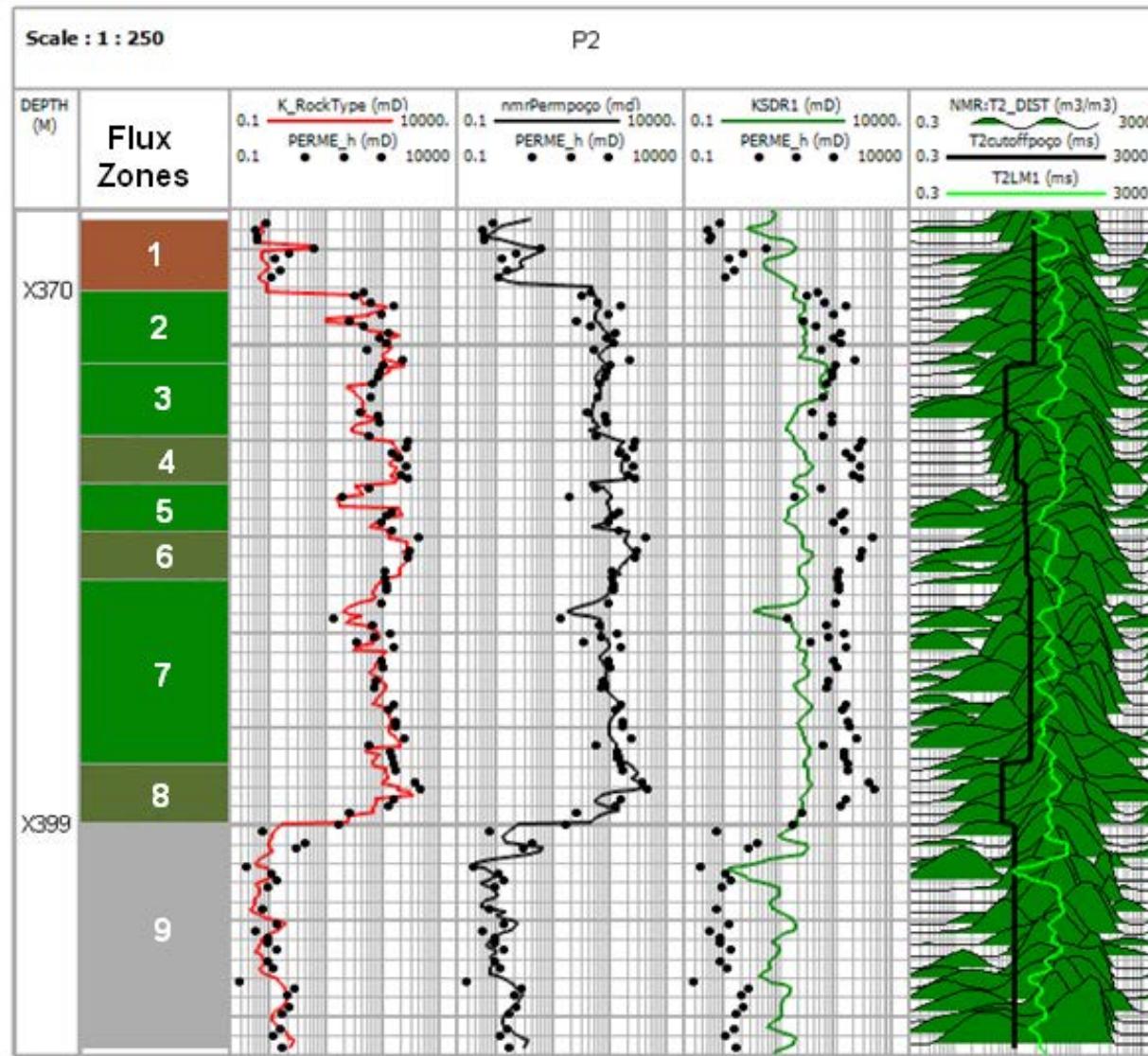


# Porosity

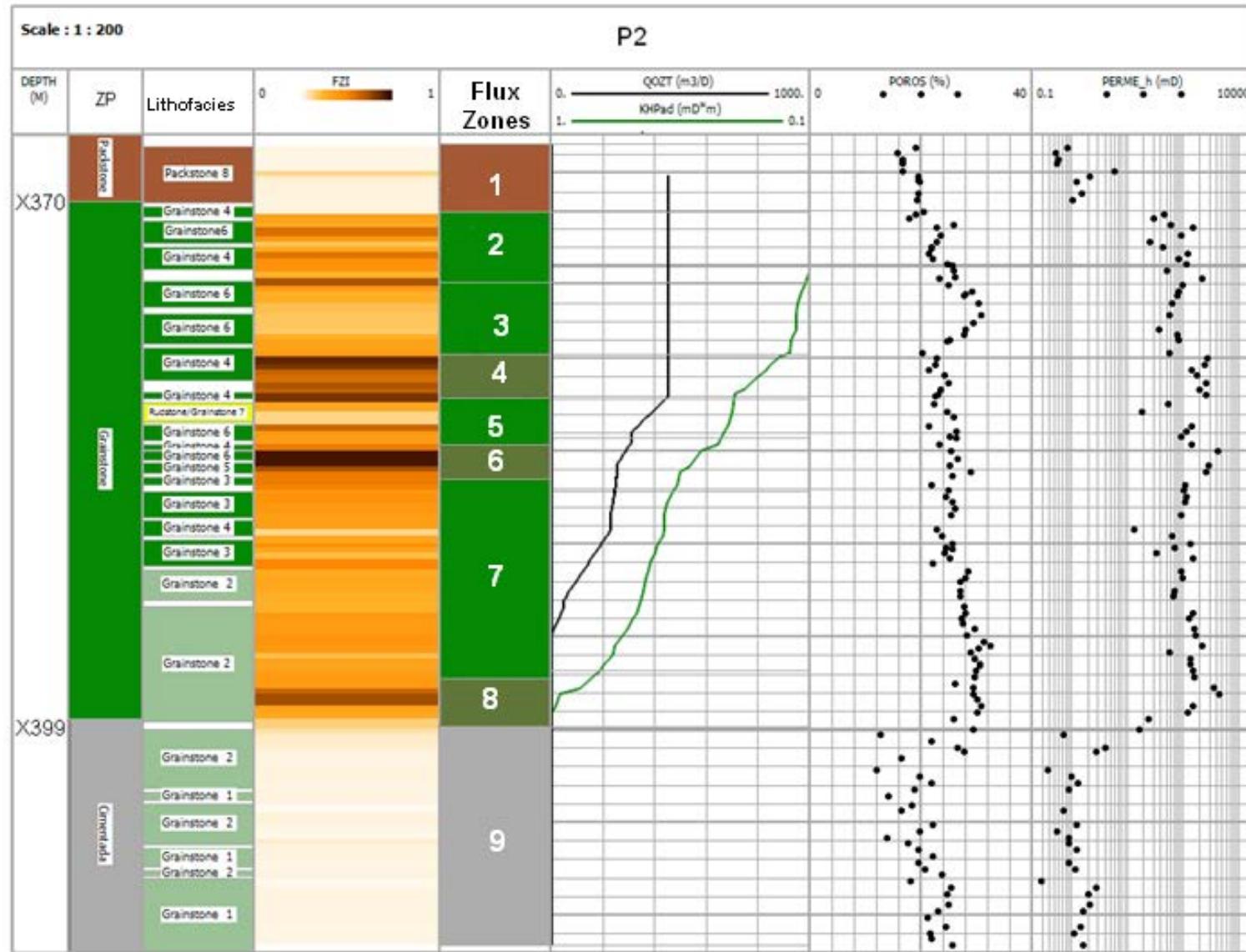


FZ	$\phi_{mínimo dec}$	$\phi_{máximo dec}$	Standard Deviation	$\phi_{médio dec}$
<b>Total Porosity</b>				
1	0.15354	0.19182	0.0096669	0.17138
2	0.18379	0.26519	0.023246	0.21296
3	0.17187	0.28587	0.037115	0.24848
4	0.1769	0.226	0.015035	0.20127
5	0.1755	0.25004	0.022978	0.2204
6	0.21564	0.29031	0.027022	0.24159
7	0.14042	0.3179	0.035367	0.24998
8	0.23072	0.2625	0.0096759	0.24939
9	0.13312	0.27508	0.037924	0.19747
<b>Porosity associated to FFI</b>				
1	0.098096	0.13583	0.010569	0.11608
2	0.12365	0.17641	0.015011	0.1498
3	0.13309	0.24443	0.033826	0.20652
4	0.14468	0.18201	0.010696	0.16046
5	0.144468	0.17772	0.010444	0.16626
6	0.16536	0.20983	0.011746	0.18641
7	0.090322	0.21541	0.025364	0.17342
8	0.19654	0.22278	0.0085258	0.21028
9	0.099589	0.19783	0.022167	0.15236

# Permeability

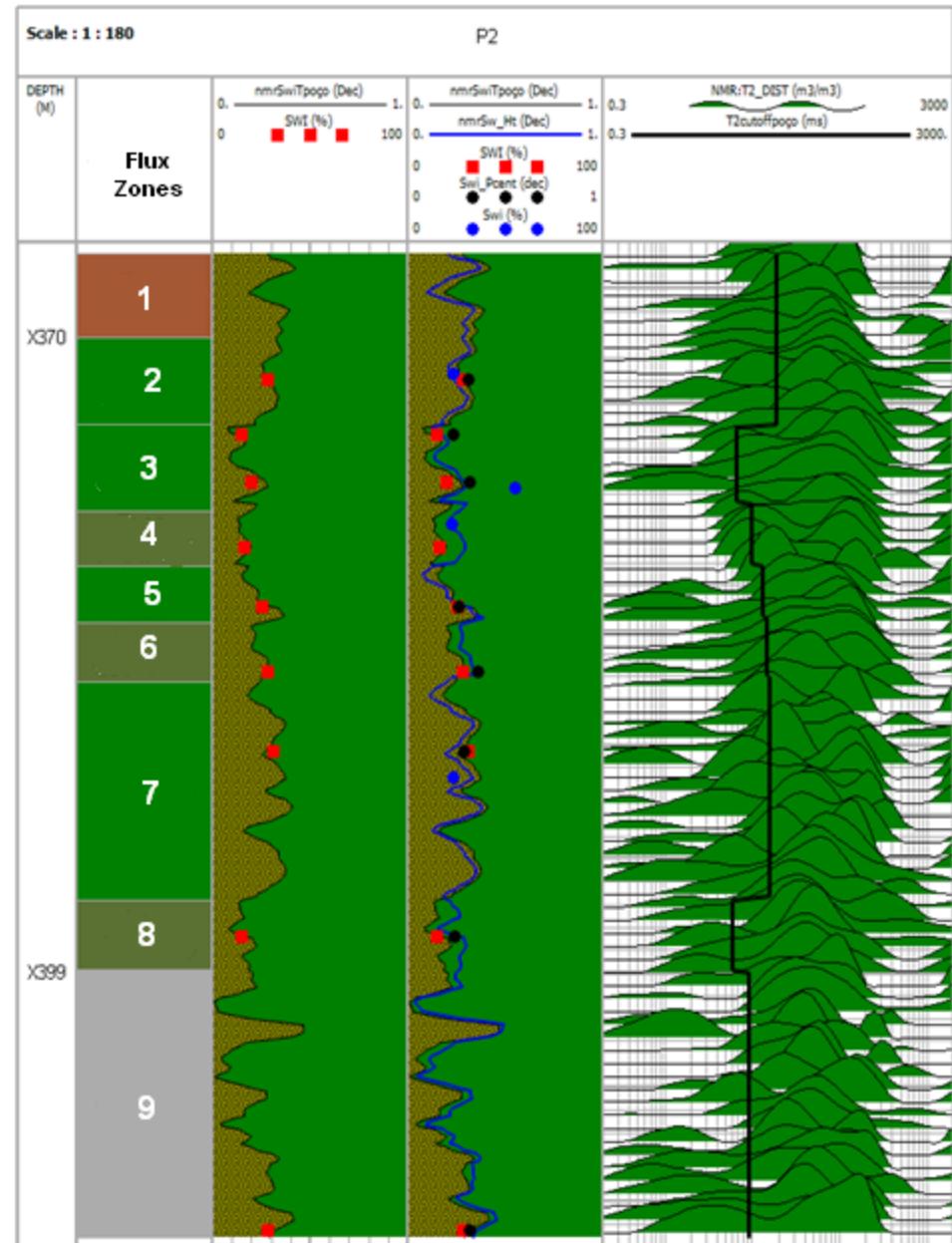


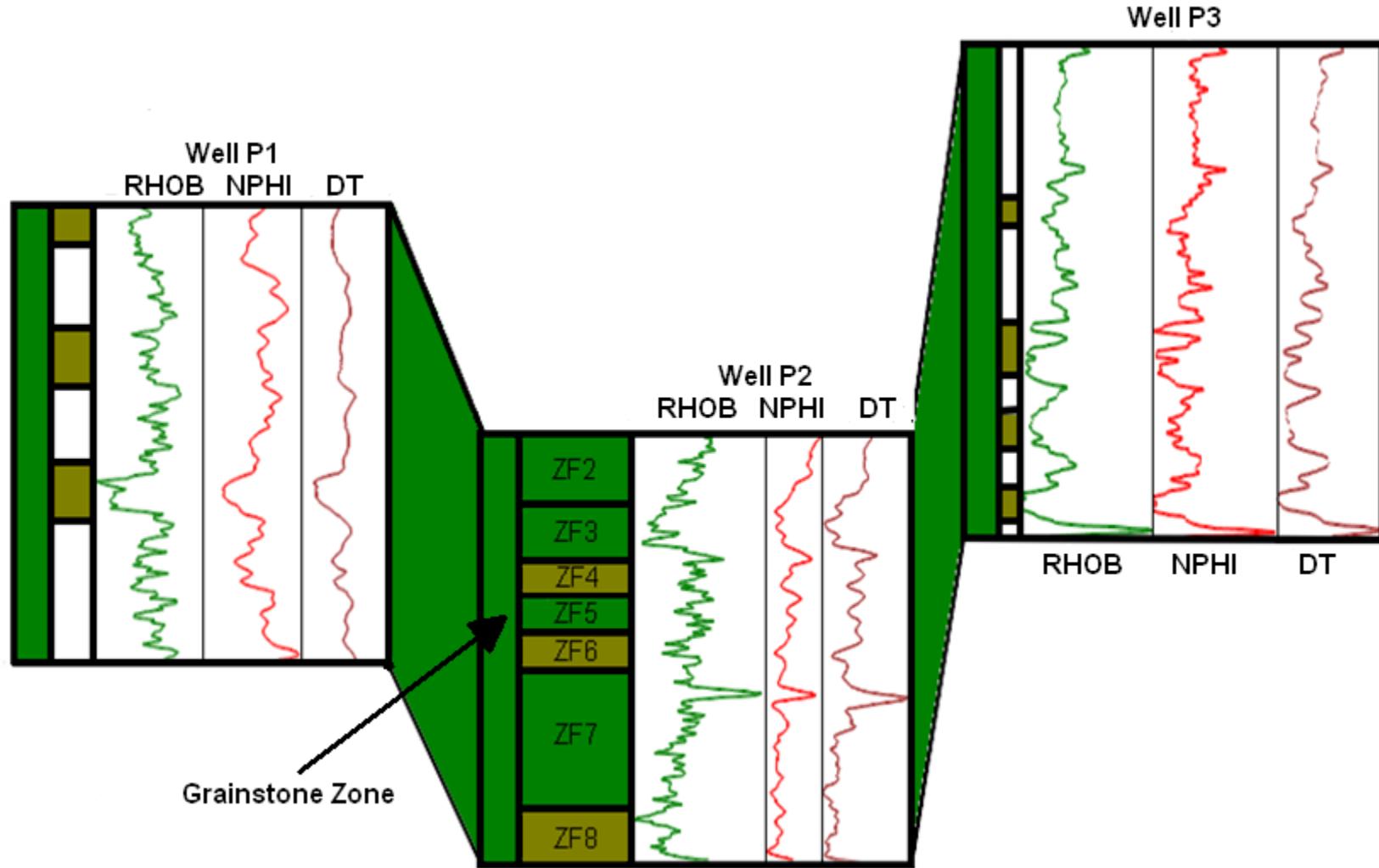
# Comparison between petrophysical model and formation test



# Irreducible water saturation

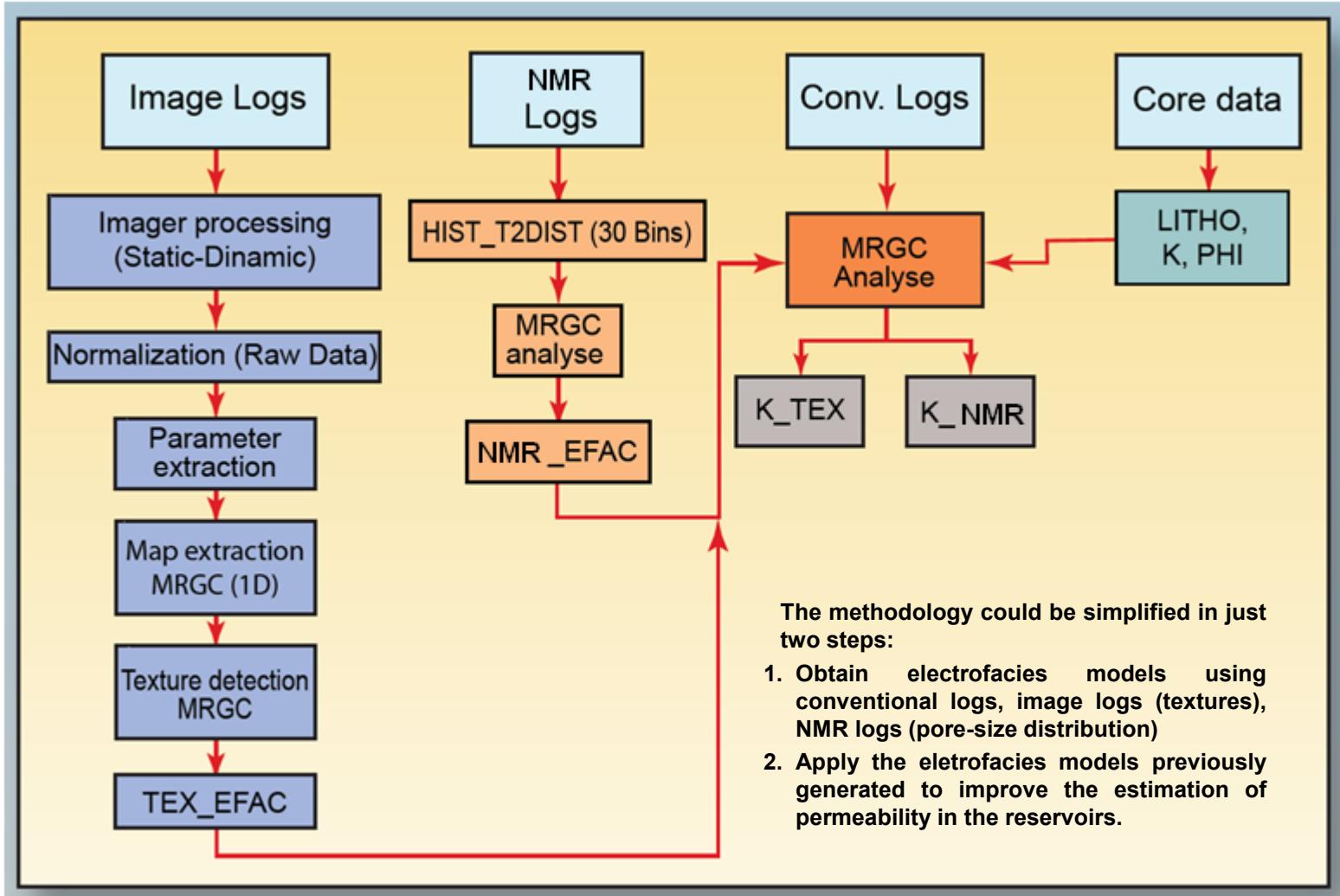
$$S_{wir} = \frac{BFT}{\phi}$$





# Work flow 2 - 1<sup>st</sup> oilfield

Marcelo Torres



MRGC = Multi Resolution Graph Clustering

# Texture estimation from image logs

- A statistical texture model proposed by Gagutowicz (1983) was used which is defined by the moments of the first and second orders of the image, i.e., histogram ( $H$ ) and auto covariance function ( $M_2$ ).
- The histogram allows the contrast of the texture to be kept, and the auto covariance function supplies information in orientation and size of texture primitives (Rabiller *et al.*, 2001).

## Histogram ( $H$ ):

$$H(l) = \frac{1}{N} \sum_i^N \delta(x_i - l)$$

Where:

**Mean:**  $\mu = \frac{1}{N} \sum_i^N X_i$

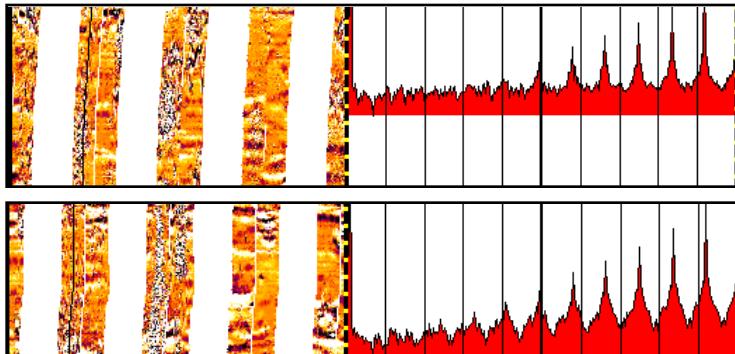
**Variance :**  $\sigma^2 = \frac{1}{N} \sum_i^N (X_i - \mu)^2$

## Auto covariance ( $M_2$ ):

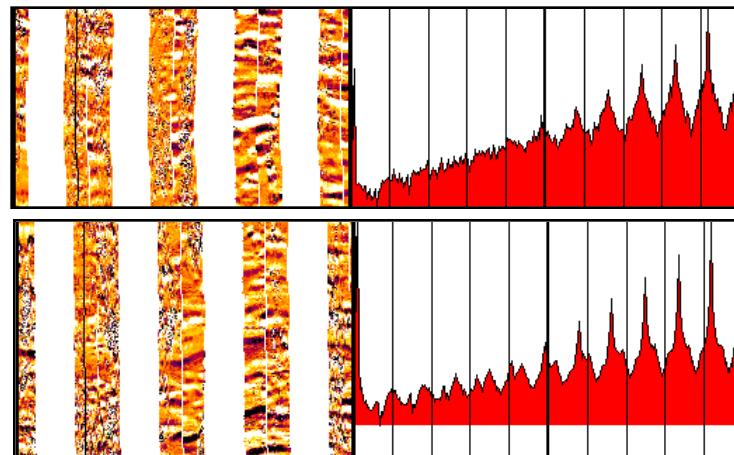
$$M_2(\Delta) = \frac{1}{N} \sum_i^N \frac{(X_i - \mu)(X_{i+\Delta} - \mu)}{\sigma^2}$$

# Parameters extraction (Texture feature log)

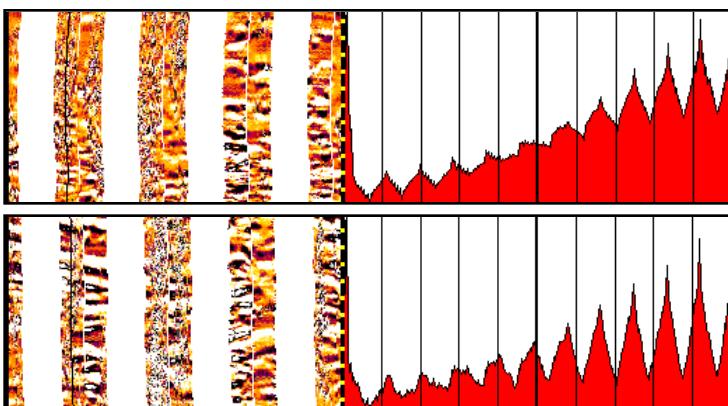
Homogeneous texture



Intermediate texture



Heterogeneous texture

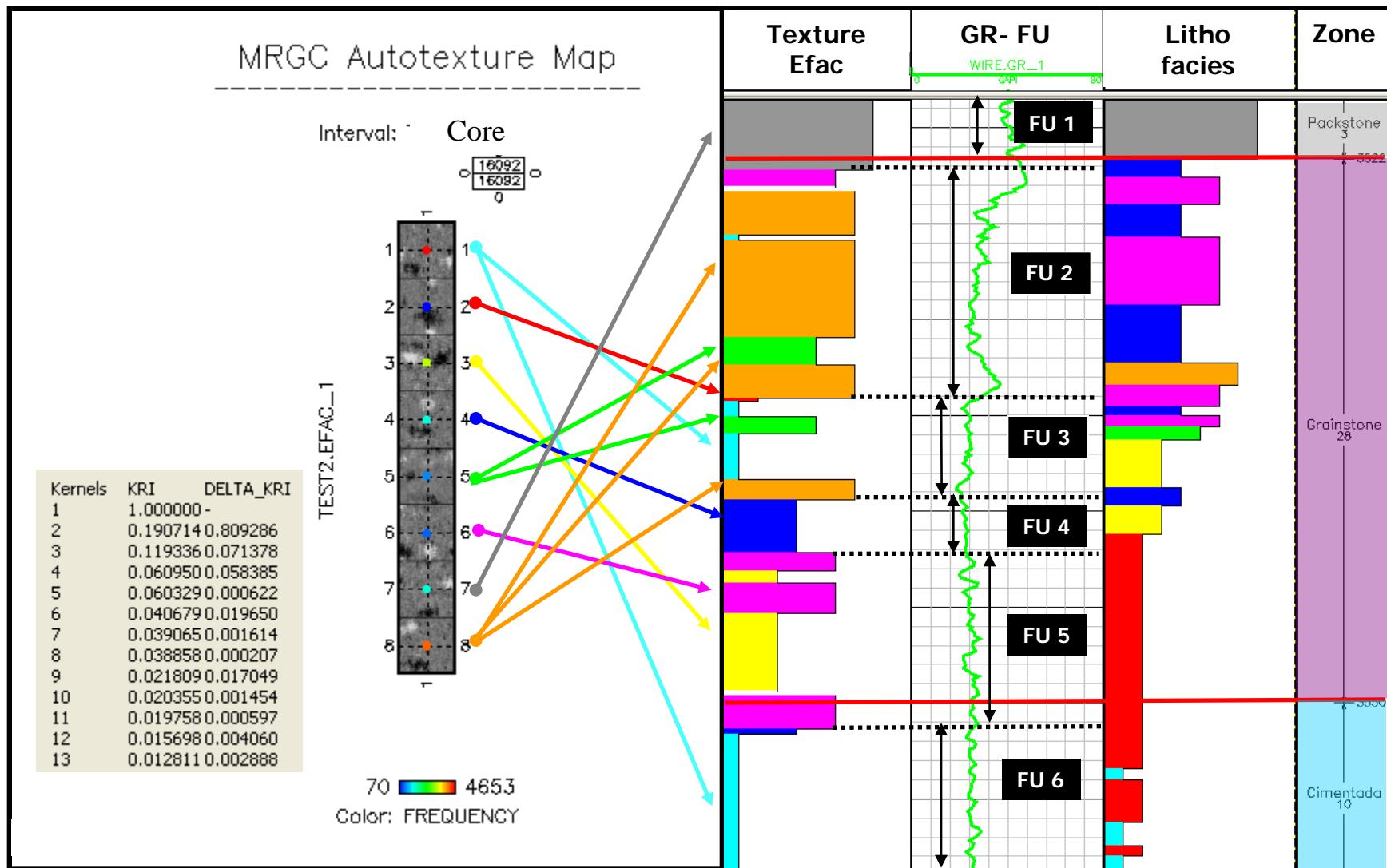


Based on the shape and appearance of the texture feature log, a descriptive analysis was carried out, showing that:

**Homogeneous textures** have an appearance dominated by the high frequency spectrum of the feature log.

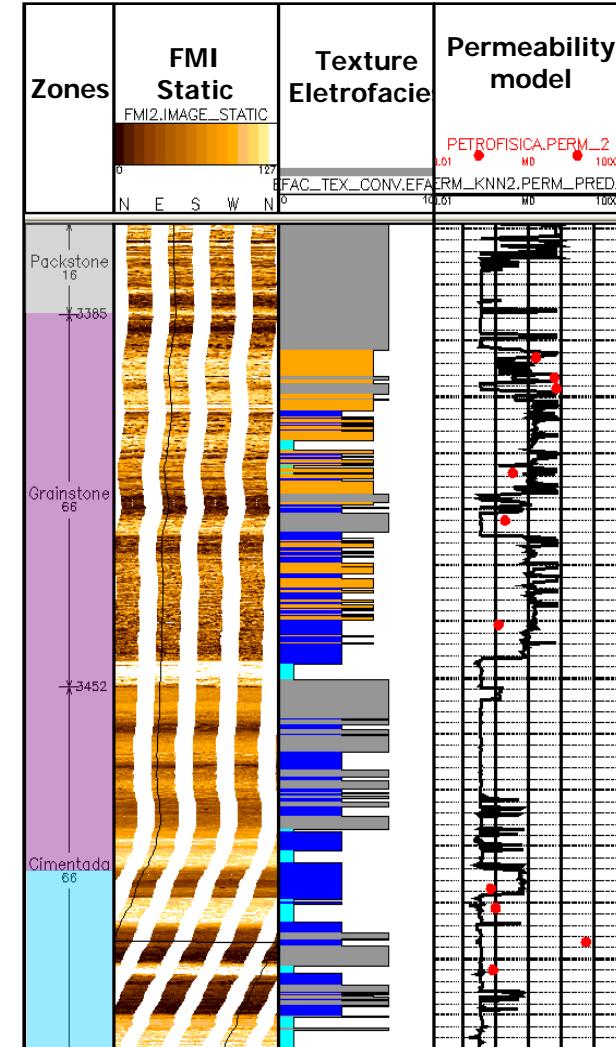
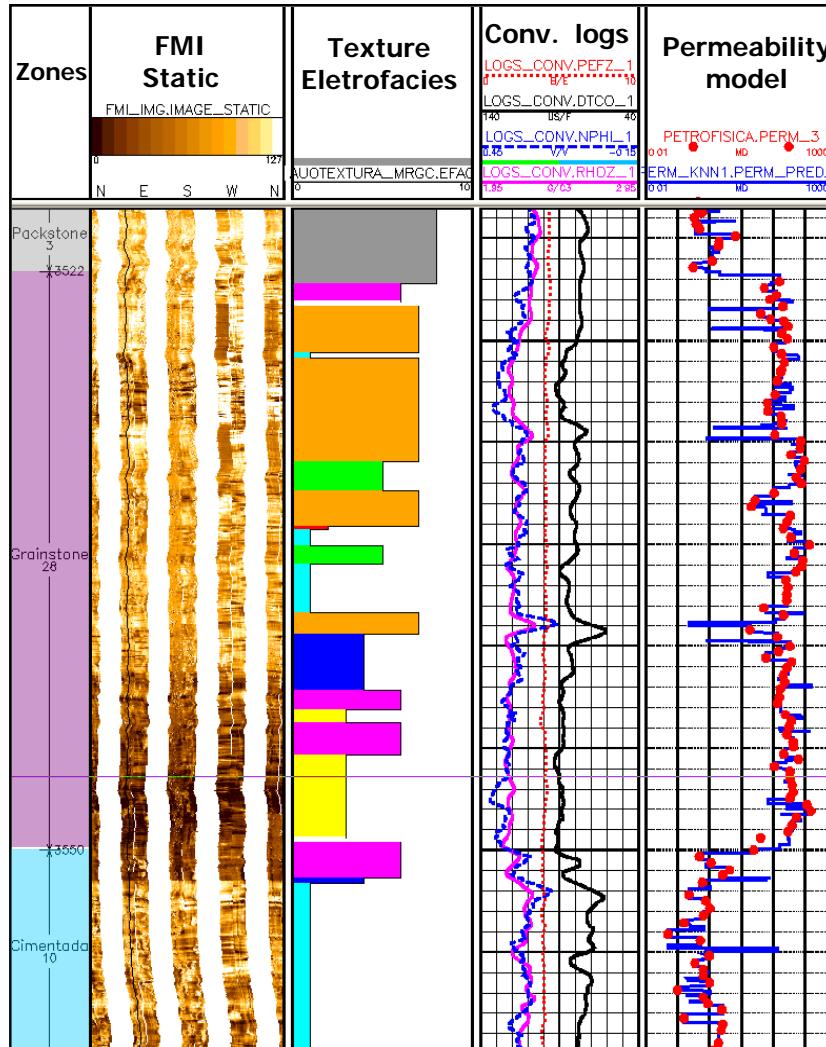
**Heterogeneous textures** show just the opposite; they are represented by the low frequency marked on the feature log.

# Texture features classification



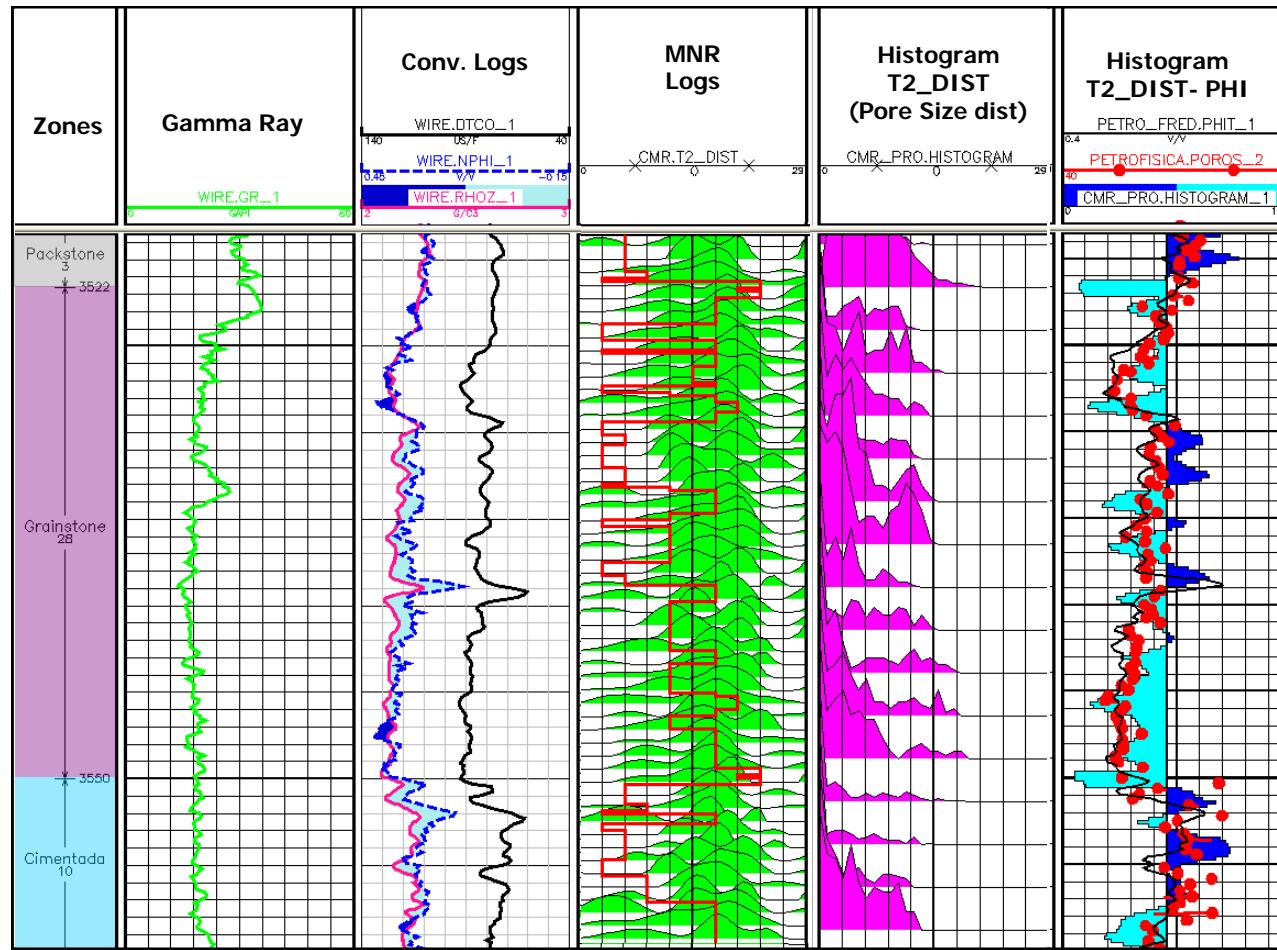
MRGC = Multi Resolution Graph Clustering

# Extrapolation of permeability texture model of Well P1 to Well P2



The light-blue textures represent the cemented levels which are very well characterized by resistive events as seen on the image logs from Well P2

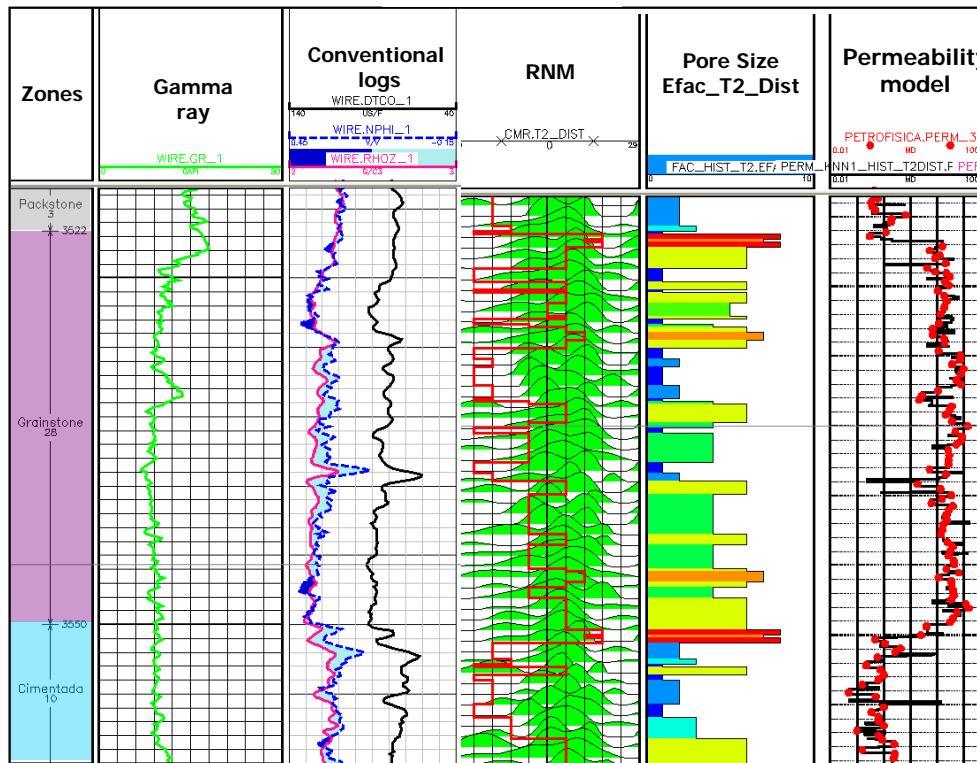
# Pore Size from NMR logs



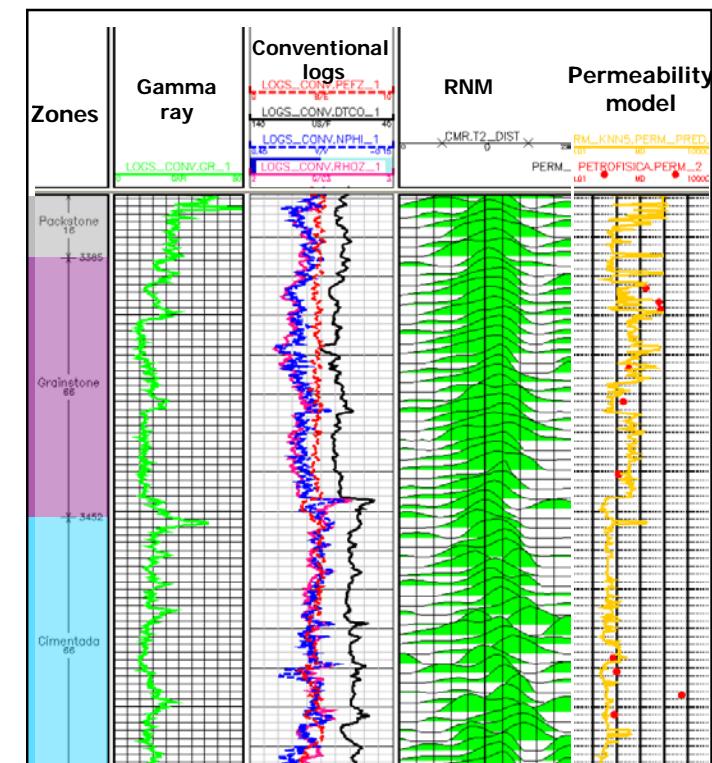
The pore-size distribution was estimated using the NMR log, from which a histogram up-scaling of the T2Dist (30 bins) was created. For this process, a window size with step length equal to the vertical resolution of the NMR log was used. The histogram was calculated using the maximum and minimum limits of the entire log.

# Permeability with pore-size distribution

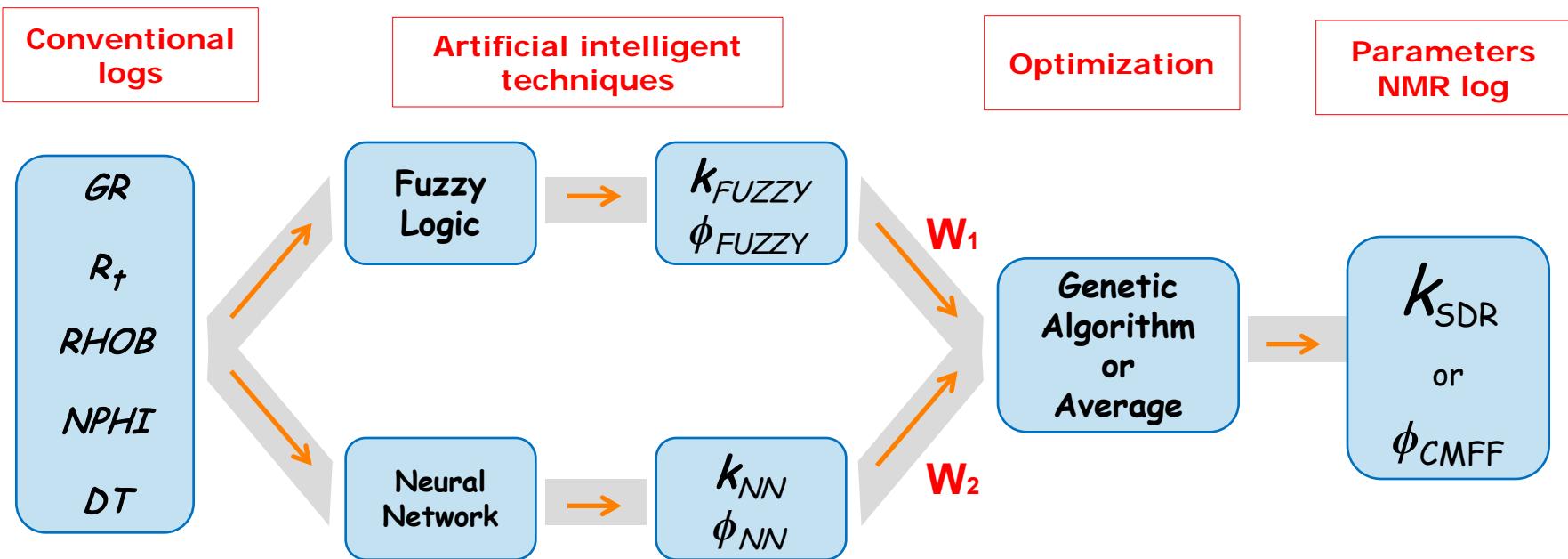
Well P1



Well P2

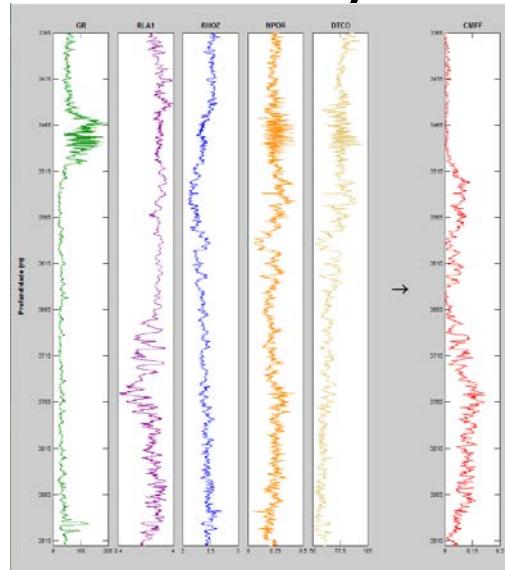


# Work flow 3 - 1<sup>st</sup> Oilfield

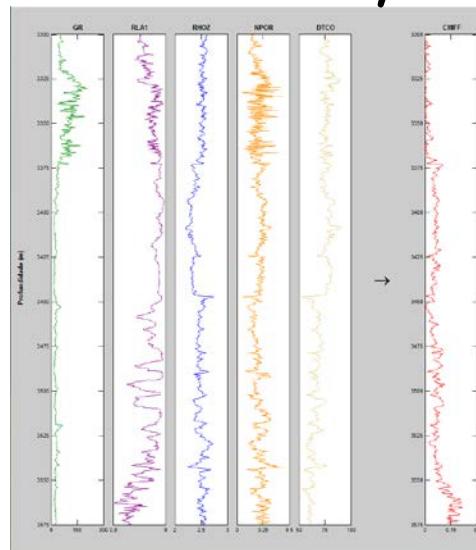


**Well P1**

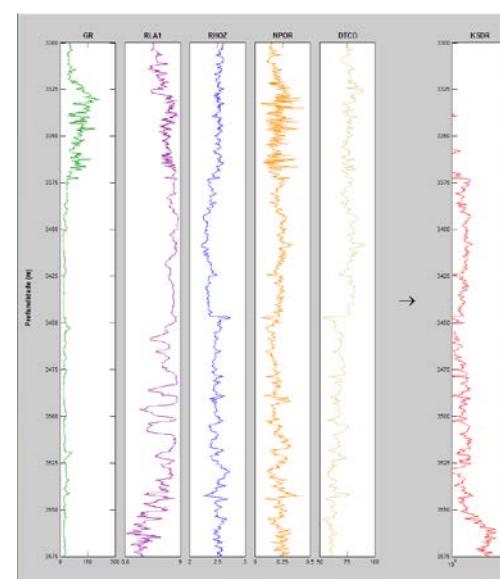
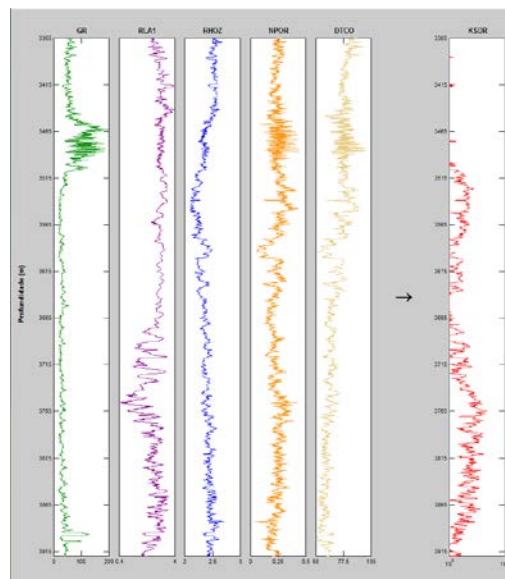
## Porosity



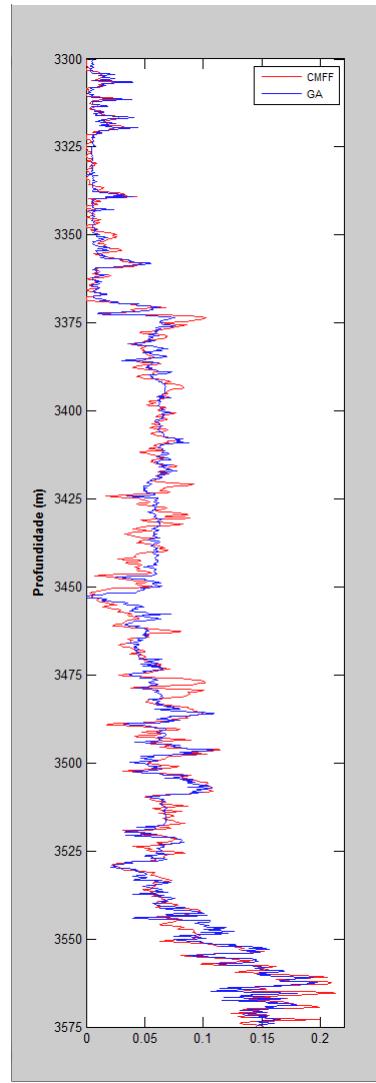
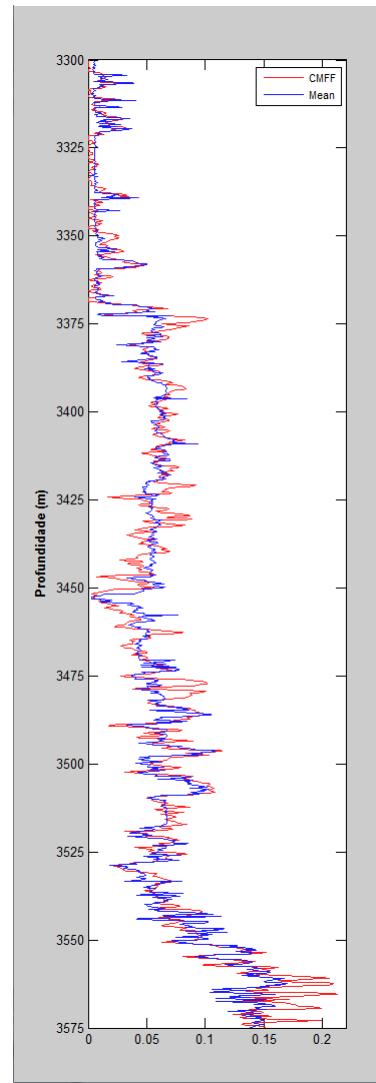
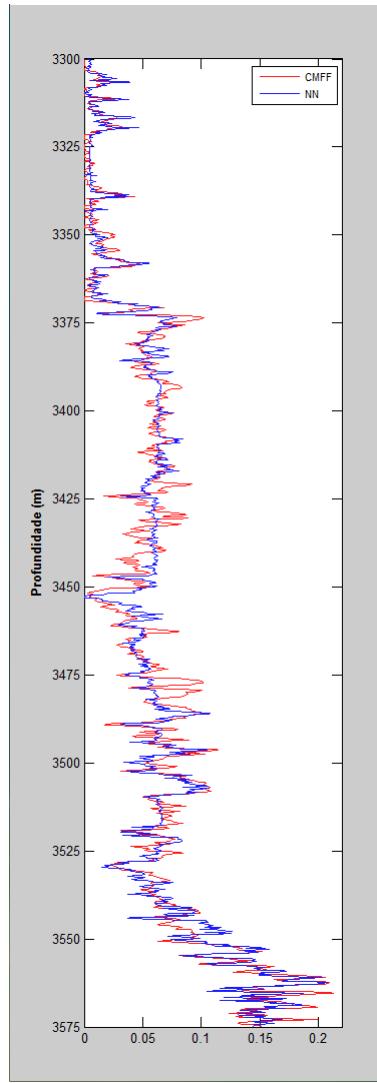
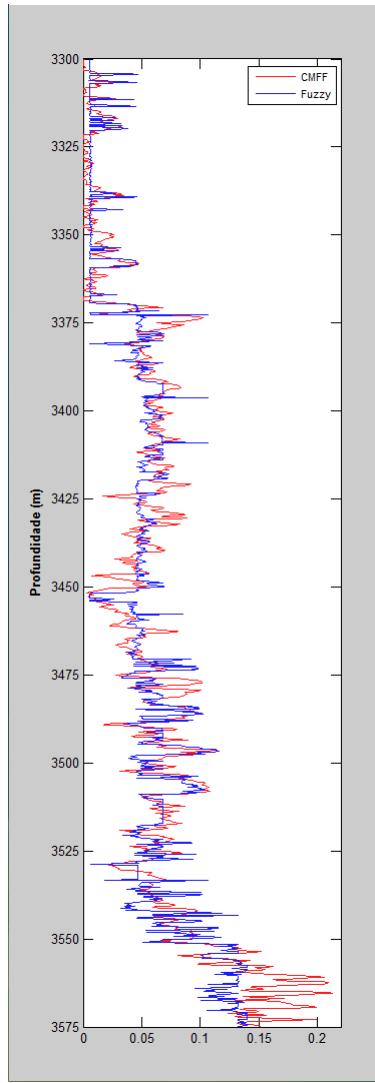
## Permeability



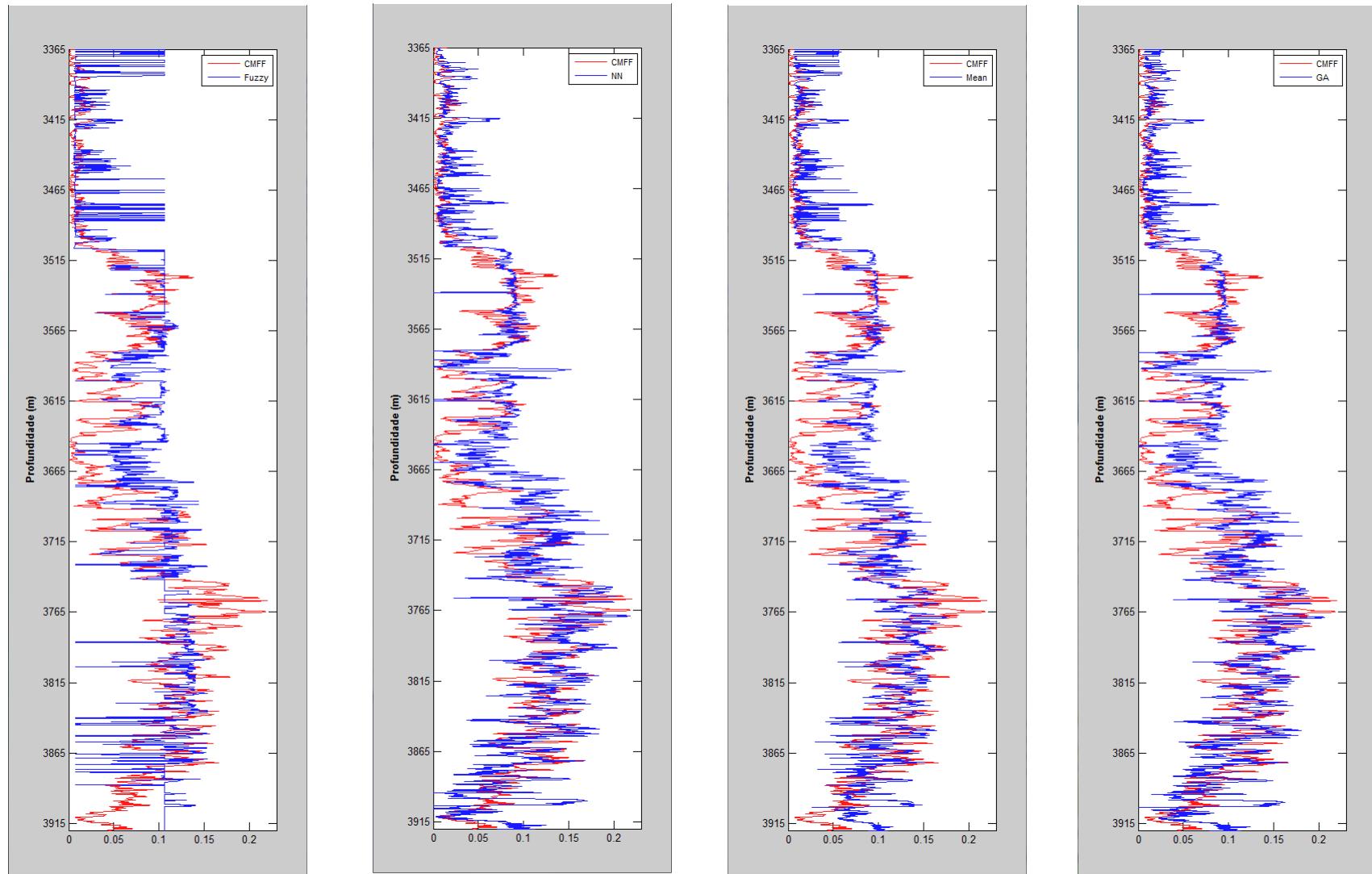
**Well P2**



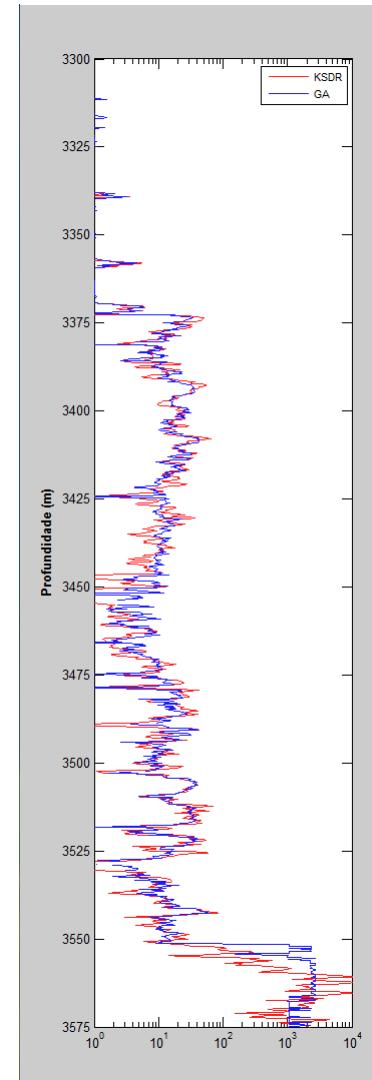
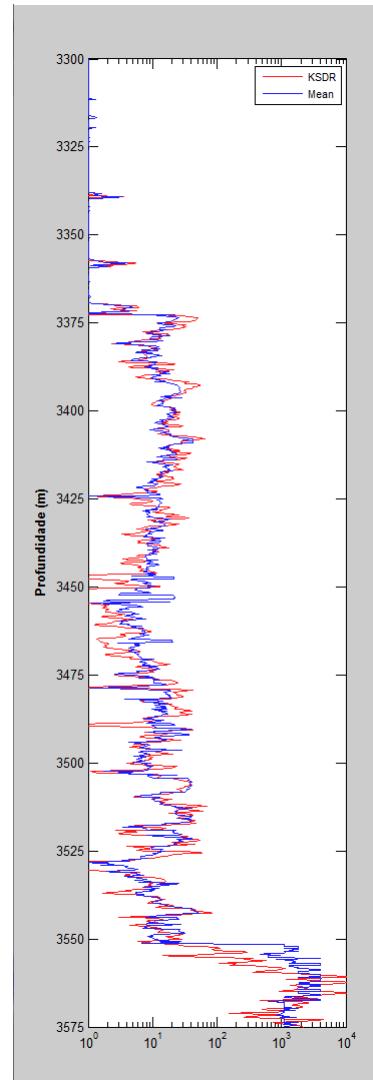
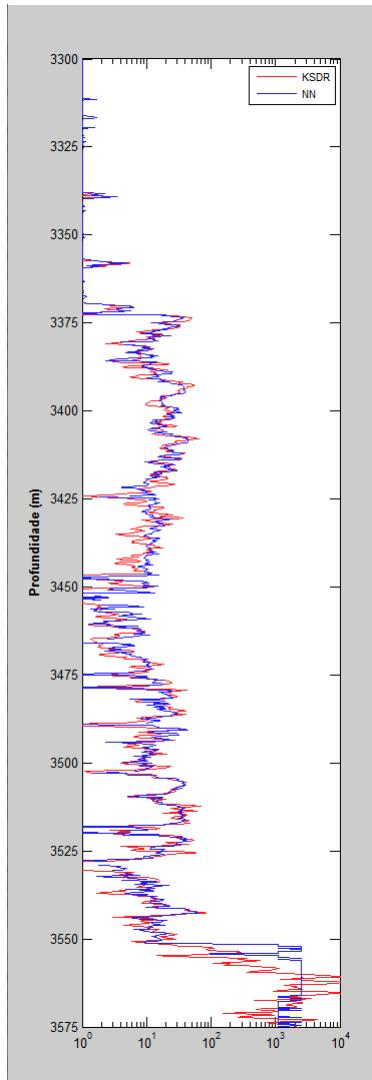
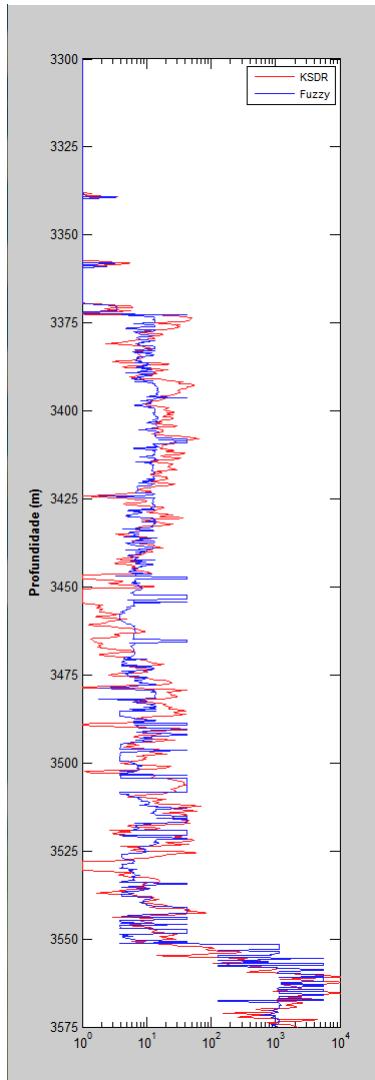
# Porosity Well P1



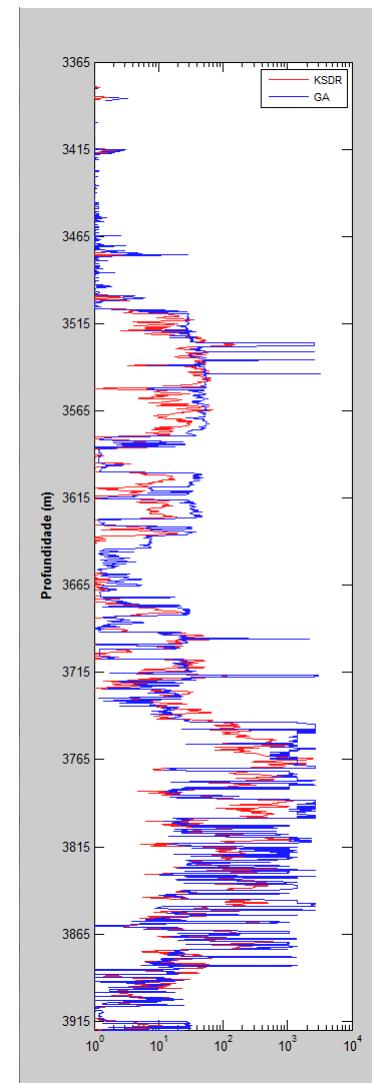
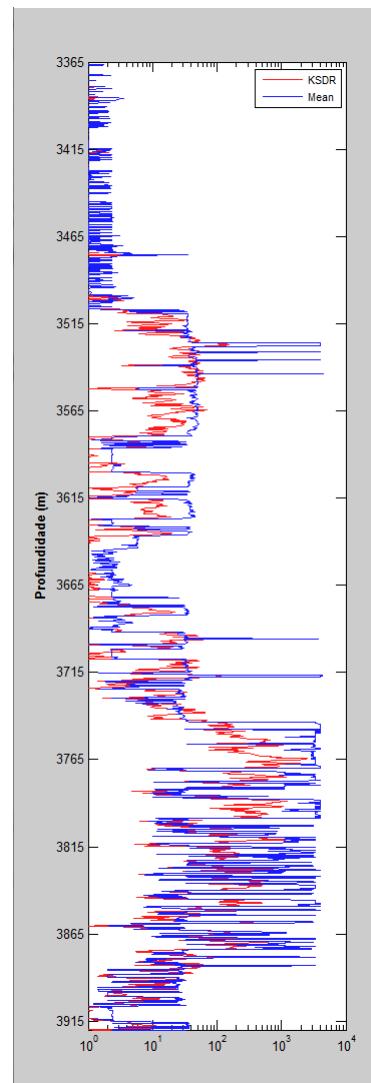
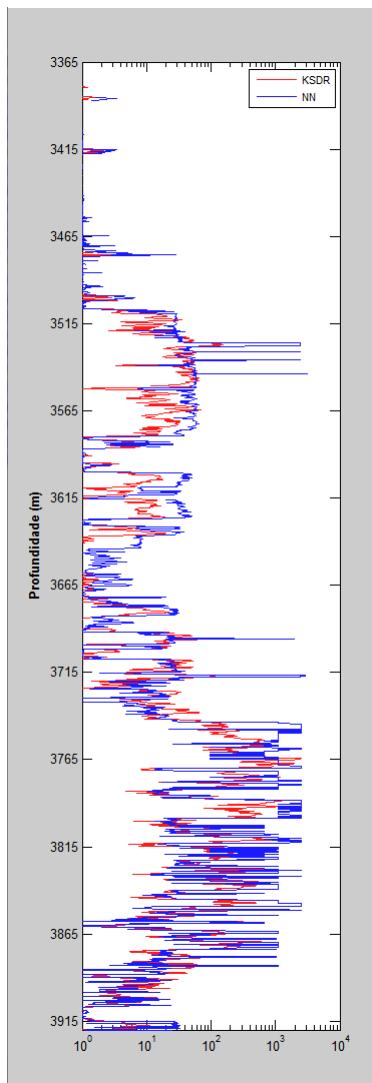
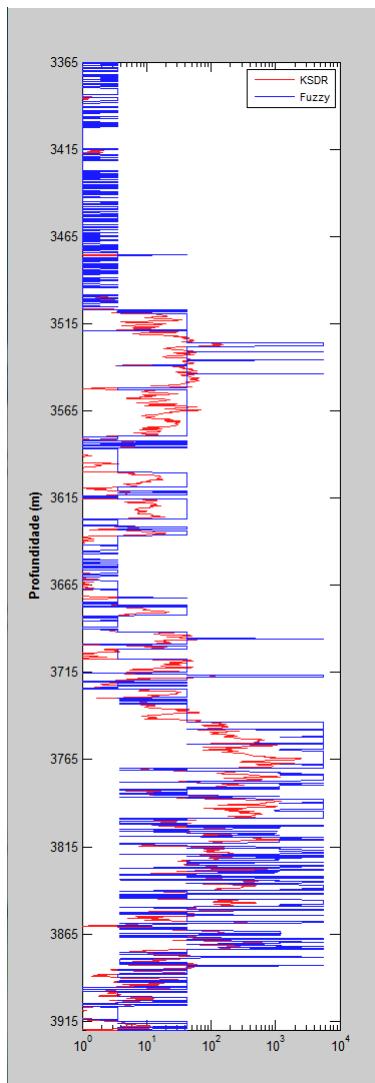
# Porosity Well P2



# Permeability Well P1



# Permeability Well P2



# Comparison of simulations

System	Reference well (Well P1)	Blind test (Well P2)		
	POROSITY			
	MSE (pu <sup>2</sup> )	Rating	MSE (pu <sup>2</sup> )	
Fuzzy	0.00035048	4°	0.00182876	
Neural network	0.00017897	2°	0.00126872	
Average	0.00020668	3°	0.00123483	
Genetic algorithm	0.00017390	1°	0.00124656	
PERMEABILITY				
	MSE (mD <sup>2</sup> )	Rating	MSE (mD <sup>2</sup> )	Rating
Fuzzy	715519.9231	4°	2999840	4°
Neural network	488169.7611	2°	254018	1°
Average	528990.8120	3°	1108540	3°
Genetic algorithm	385011.4734	1°	300658	2°

# Work flow - 2<sup>nd</sup> Oilfield

$$RQI = 0.0314 \sqrt{\frac{K}{\phi}}$$

Plot data and reservoir evaluation

$$\log S_w = \left( \frac{1}{n} \right) (\log a + \log R_w - \log R_t - m \log \phi),$$

Archie linearization

$$x = (A^T A + \delta I) A^T y,$$

Archie parameters calculation  
( $a, m, n$  e  $R_w$ )

Reference well

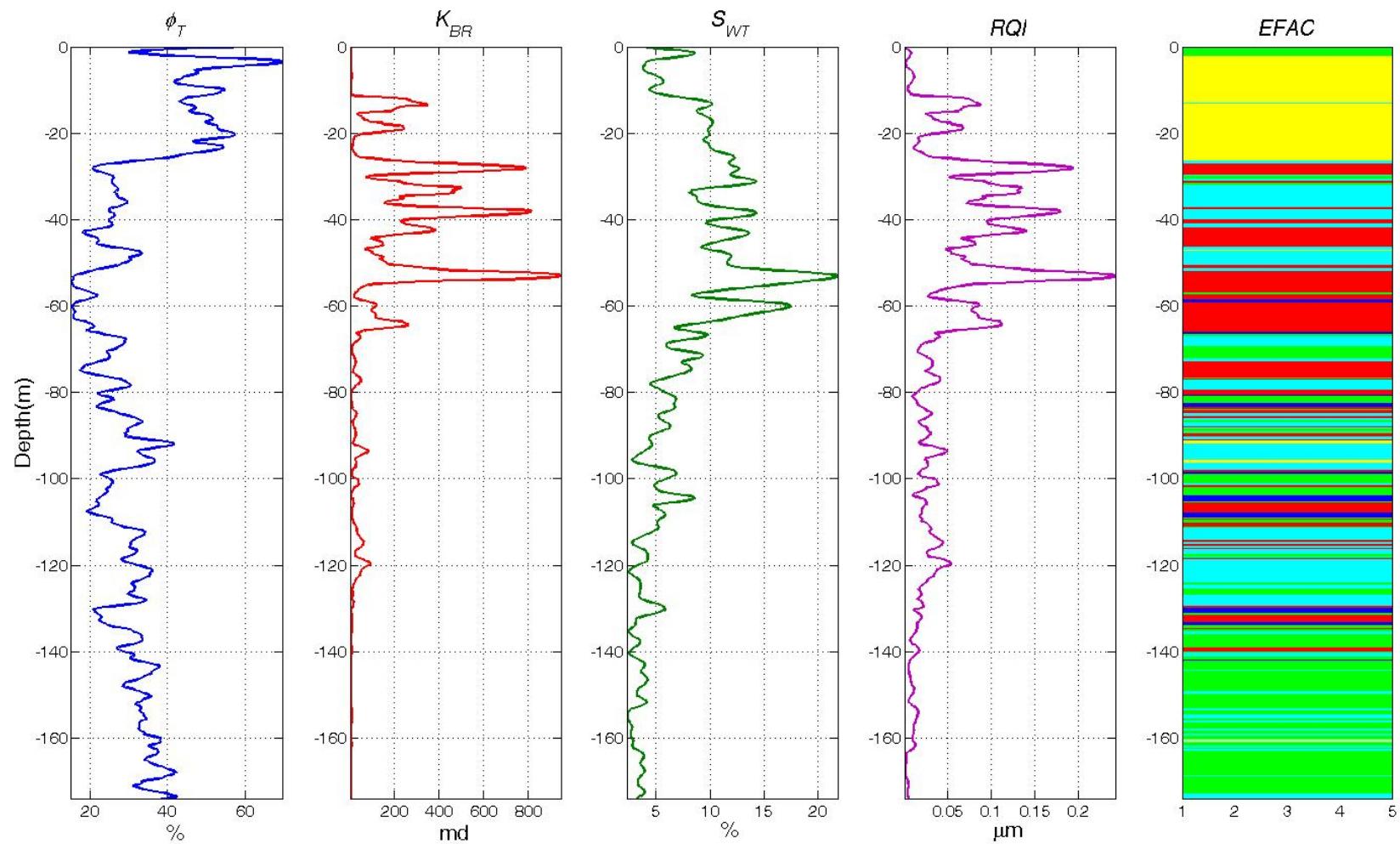
Finish

Good

Blind test

Not good

# Well A3



**Energy**

+high

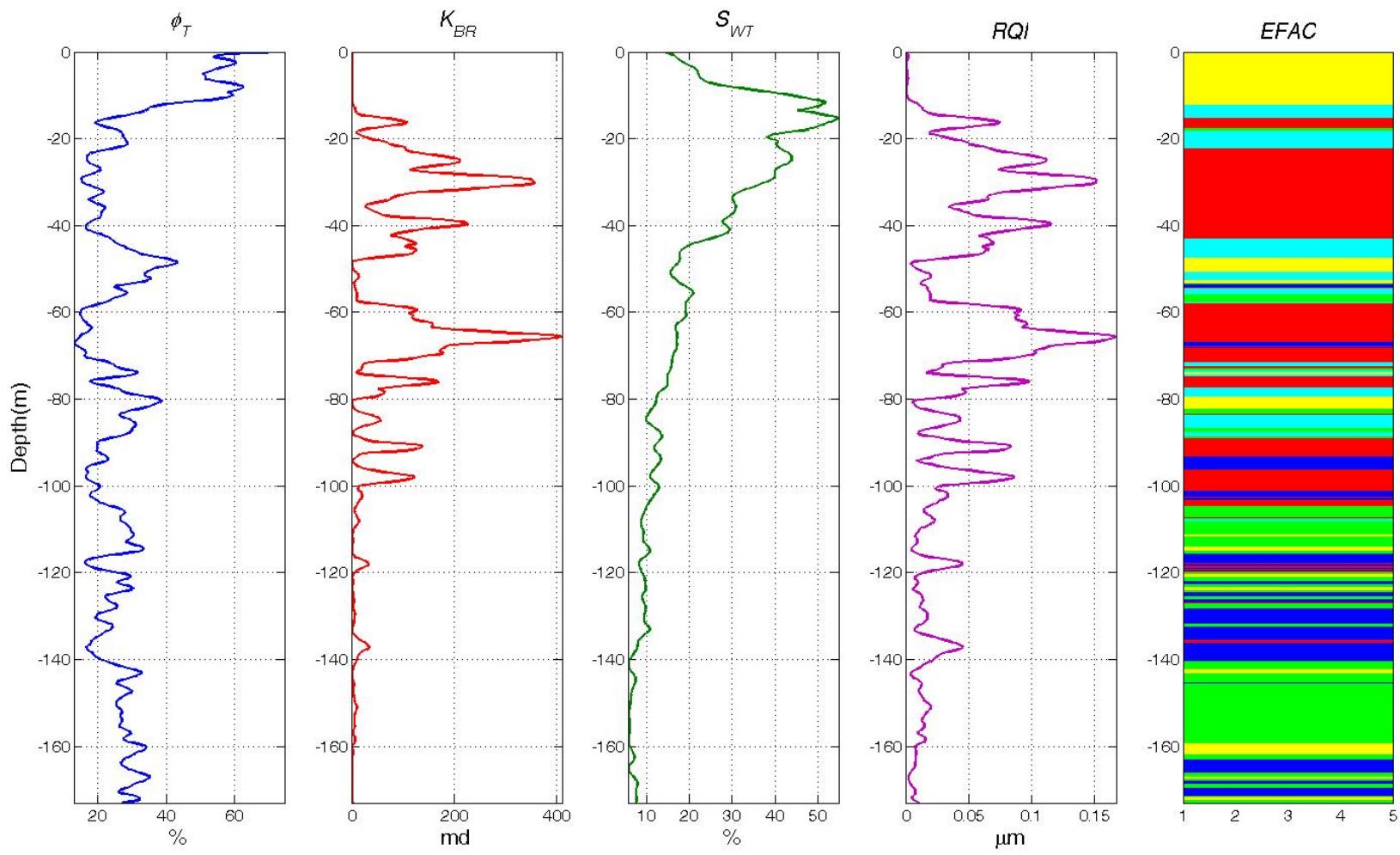
-high

medium

-low

+low

# Well A10



**Energy**

+high

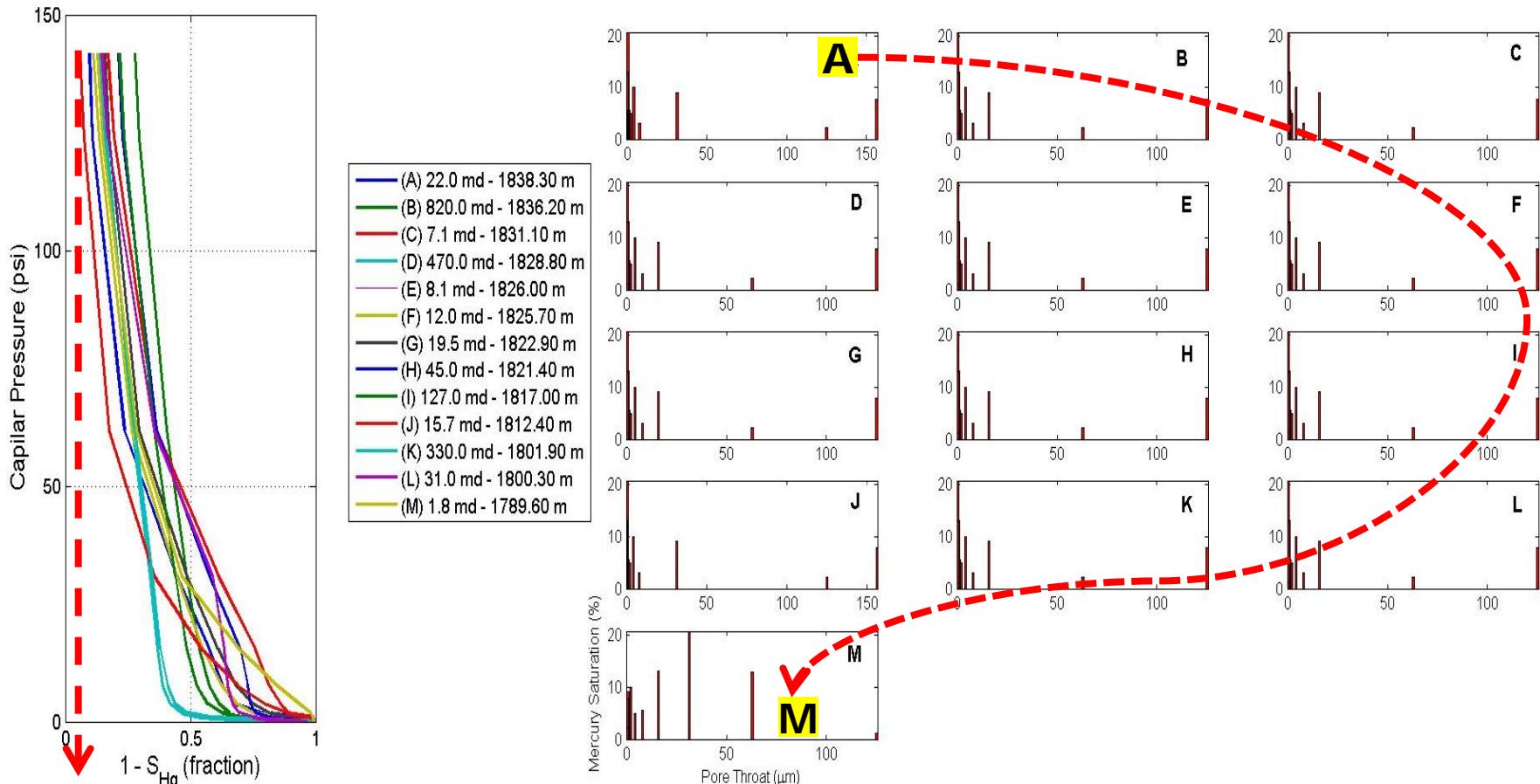
-high

medium

-low

+low

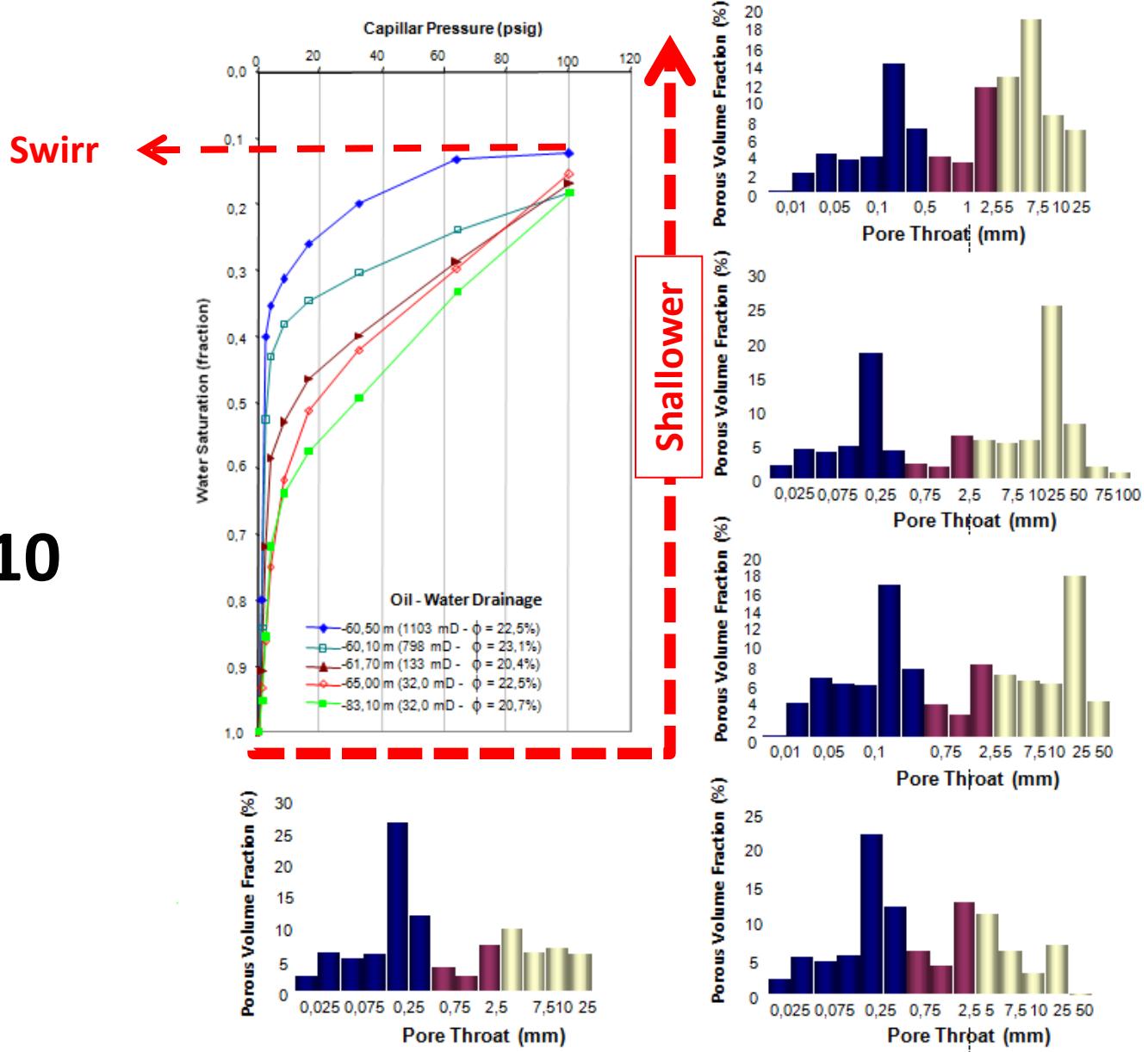
# Well A3

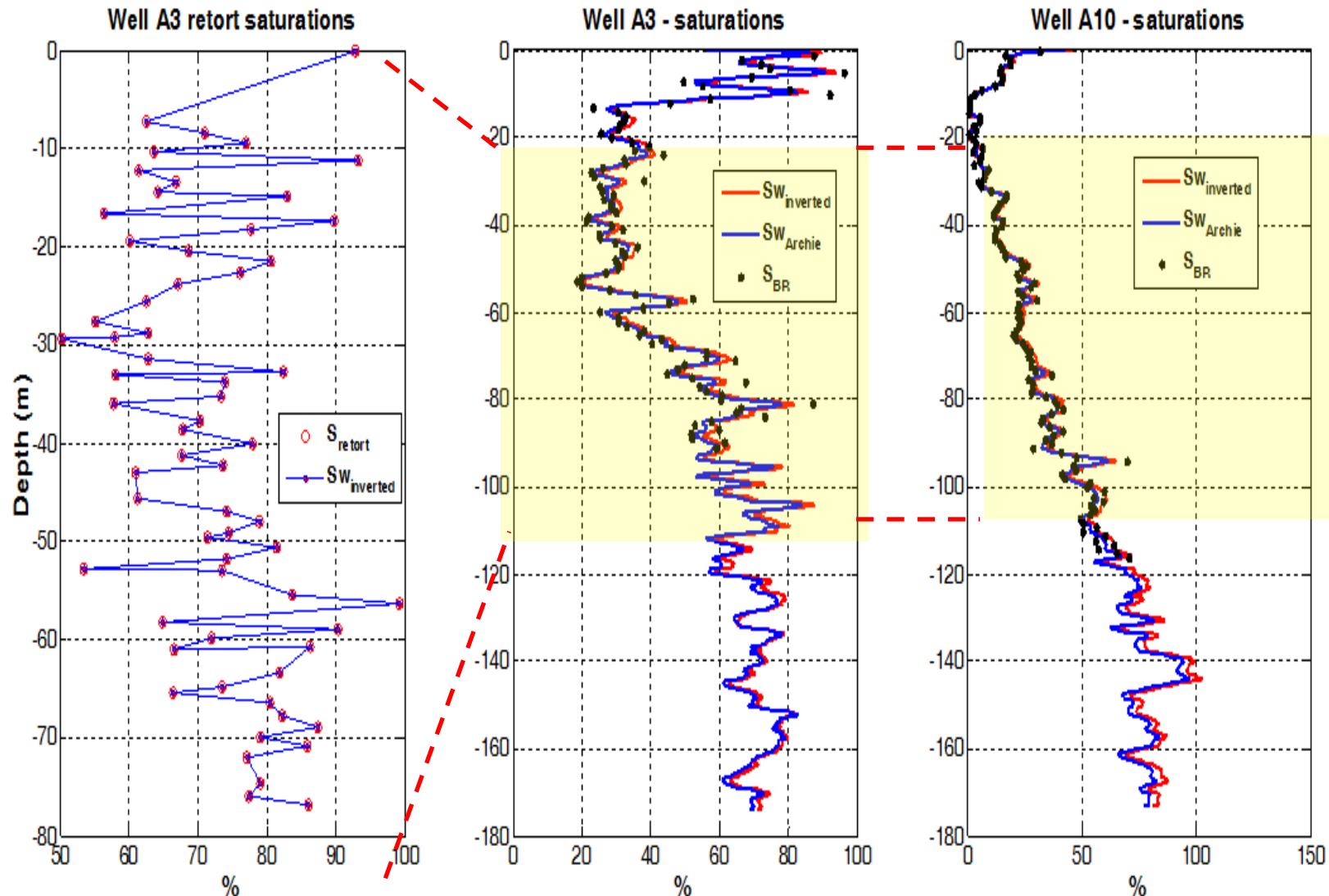


Swirr



# Well A10





$$a = 1.0098; m = 2.1000; n = 2.1000; R_w = 0.0437$$

$$a = 1; \quad m = 2; \quad n = 2; \quad R_w = 0.02$$

# Conclusions

- In the two oilfields of Campos Basin, the integrated methodology shows that the resulting interpretation is much more reliable.
- In the first oilfield, we reached similar models to permeability and porosity through different approaches - flux zones and statistics with images logs.
- Also in this oilfield, the flux zone results obtained from static NMR measurements are similar to results of dynamic formation tests.
- For the second oilfield, the carbonates reservoir is shown as an Archie reservoir, that is, with characteristics of a sandstone reservoir, as shown by the values of Archie equation coefficients.

## ACKNOWLEDGEMENTS



**anp**  
Agência Nacional  
do Petróleo,  
Gás Natural e Biocombustíveis



**Thanks!**