Hydraulic unit determination and permeability prediction based on flow zone indicator using cluster analysis

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SLIDE 3

OUTLINE

- THE CONTEXT.
- JUSTIFICATION.
- SUPERVISED LEARNING
- CLUSTER ANALYSIS
- ROCK TYPING ASSISTED BY CLUSTER ANALYSIS.

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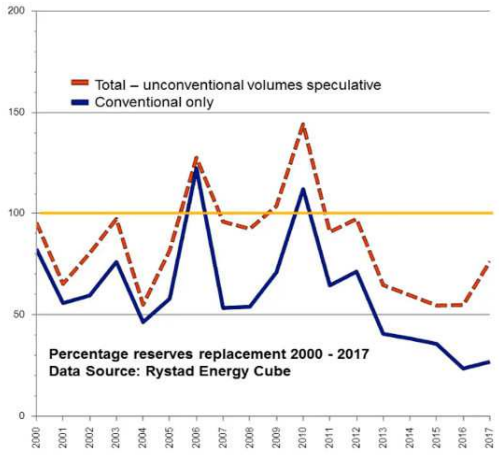
THE CONTEXT

Source: Rystad Energy Cube



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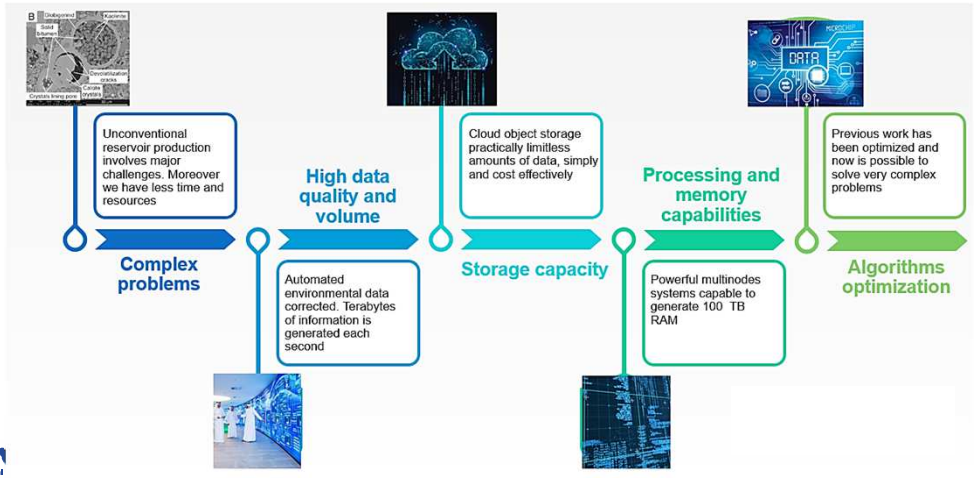
THE CONTEXT



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JUSTIFICATION

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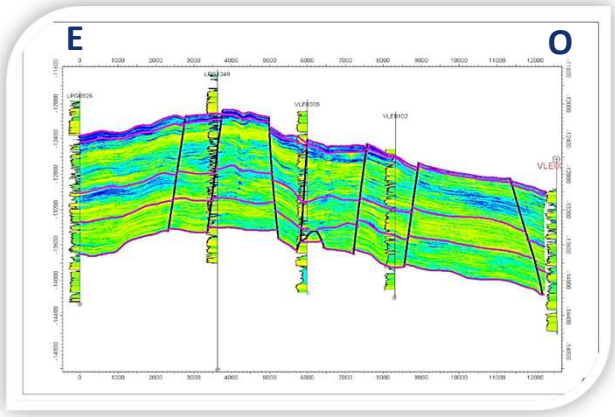
Rock typing is challenging due to lateral facies changes and complex pore structures



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JUSTIFICATION

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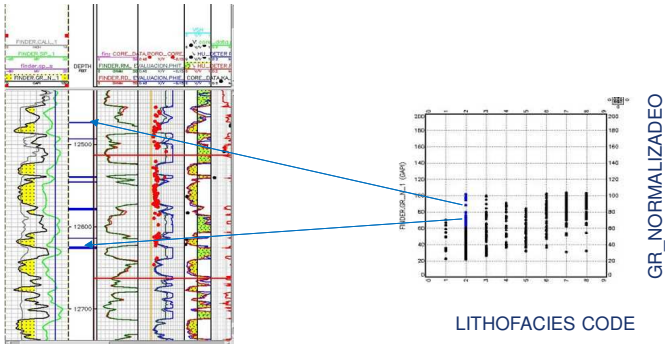
Dimensionality problem: According to Rabiller the differences among the relative distances between classes in the log space and geological space causes a strong non- linearity.



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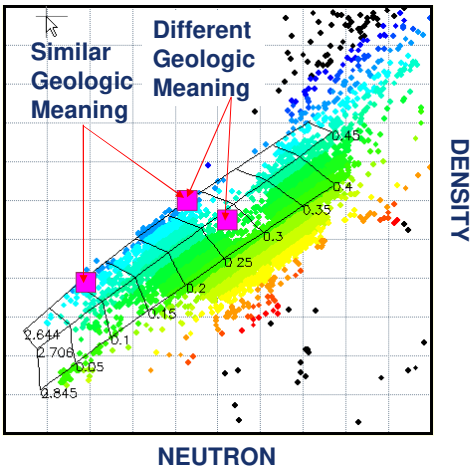
JUSTIFICATION

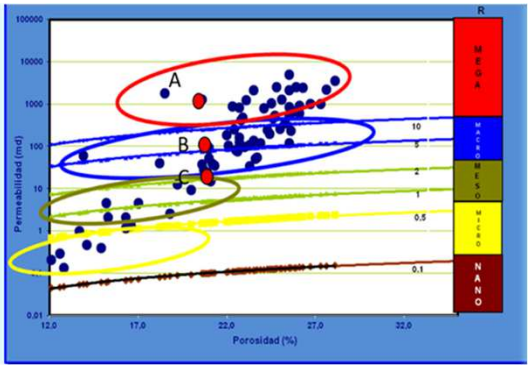
Dimensionality problem:

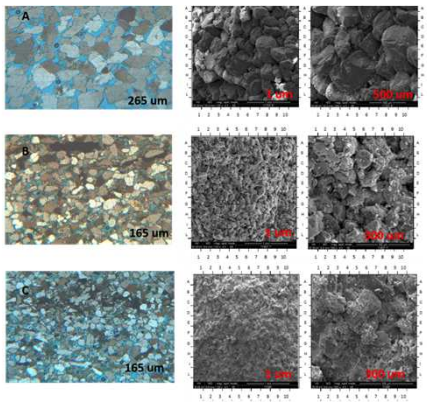


Taken from "Introduction to Facimage" **Paradigm-Emerson**

JUSTIFICATION

Reservoir heterogeneity





Aguilar, C; Romero, E. 2013."Flow unit determination using FZI and PTR. Core VLE-XX54, Reservoir C-X2 VLE-XX96 area, Block V Maracaibo Lake". SPE-WVS305. 2nd Oil and Gas Suramerican Congress.

THE ANSWER

To use machine learning algorithms to "learn" information directly from data without relying on a predetermined equation as a model. The algorithms adaptively improve their performance as the number of samples available for learning increases.

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SUPERVISED LEARNING

SUPERVISED LEARNING

A supervised learning algorithm takes a known set of input data and known responses to the data and trains a model to generate reasonable predictions for the response to new data. Supervised learning uses classification and regression techniques to develop predictive models.

- Classification techniques predict discrete responses: classify input data into categories. Rock typing, lithofacies.
- Regression techniques predict continuous responses— for example, permeability, density log, shear dt.

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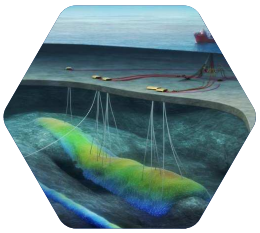
SUPERVISED LEARNING

OBJECTIVES

- To predict accurately “hard data”
- Understand relationship between training data and independent variables
- To quantify errors and uncertainties



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PRELIMINARY WARNING

- Be careful with automated process.
- Learn about “math” behind of the algorithms
- Spend time in:
  - QC.
  - Uncertainties evaluation.

CLUSTERS ANALYSIS

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CLUSTERS ANALYSIS

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ALGORITHMS

Statistical methods analyze the underlying Probability Density Functions (PDF) of observation distributions.

NONPARAMETRIC METHODS

Do not use any statistical model to underlying PDF distribution model

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CLUSTERS ANALYSIS

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MRGC Advantages :

- Does not need any priori knowledge to perform the clusters analysis.
- Capable of recognize different shapes clusters.
- Capable of recognize different sizes clusters.
- It is not very sensitive to variations of the input parameters.

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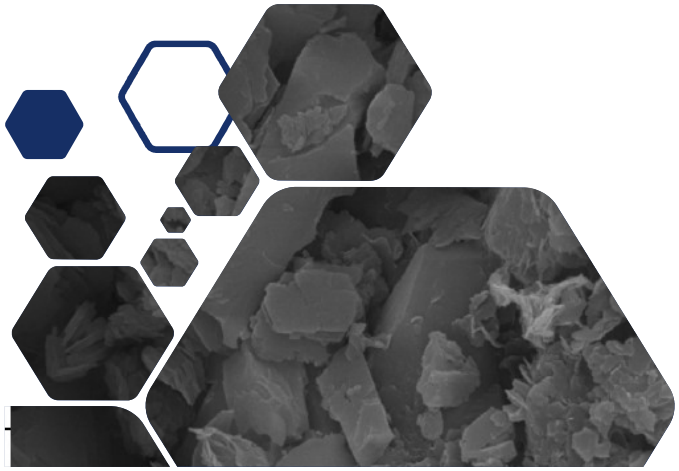
ROCK TYPING



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GENERALITIES

Reservoir under study is an Eocene shaly sandstone reservoir located at the center of the basin of Lake Maracaibo (Venezuela), Sand deposits are primarily of channel-type corresponding to a fluvial-deltaic deposition system. The field starts to produce at 1959, is a brown field and it have been under water and gas injection. The main purpose of this detailed characterization is identified new infill drilling opportunities and by–passed oil zones in the reservoir. Four (04) cores were available, with a total core lenght of 2170.4 ft, total area above of 103 KM2, and 161 wells.

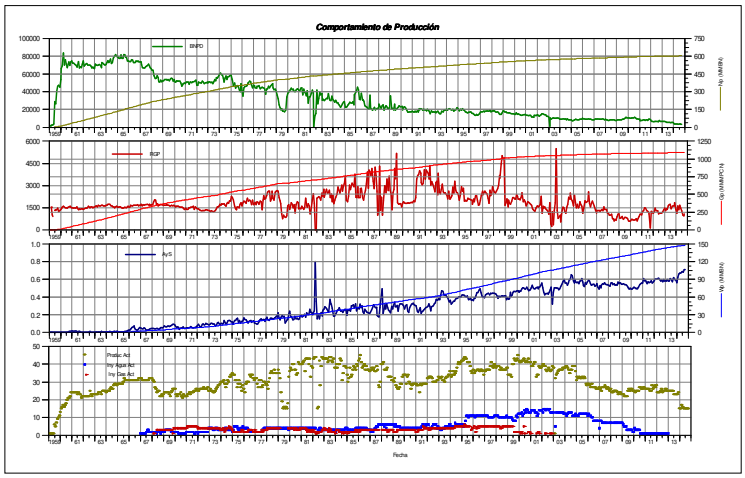
RESERVOIR PRODUCTION BEHAVIOR

Oil

Gas

Water

Active wells

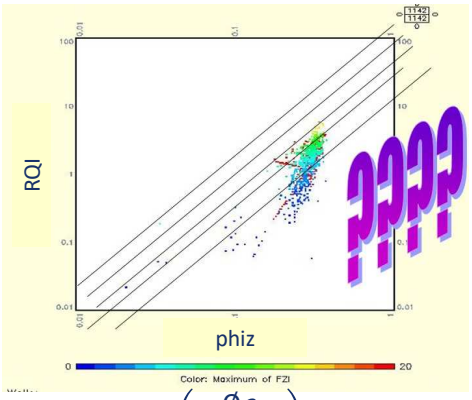


FZI DEFINITION

AMAEFULE METHODOLOGY

Based on Kozeny-Karman

$$0.0314 * \sqrt{\frac{k}{\emptyset e}}$$

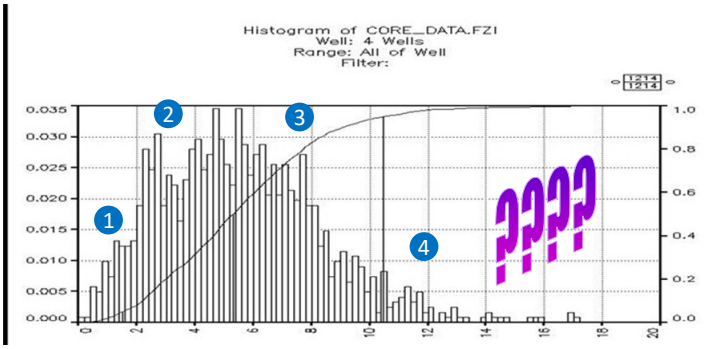


1142 Core samples

$$\left(\frac{\emptyset e}{1-\emptyset e}\right)$$

FZI DEFINITION

SIMPLISTIC APPROACH: PDF & CDF FZI ANALYSIS



CLUSTER ANALISIS

BEST PREDICTORS USING CROSS VALIDATION

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CROSS-VALIDATION BEST PREDICTORS FOR SUPERVISING FACIES:

Supervising facies log with 6 facies
Total reassignment error by cross-validation
Best 6 predictors:  DT        DRHO      VSH_STB2  CALI   RD     PHIE   error =   7.738%
Best 5 predictors:  DT        DRHO      VSH_STB2  CALI   PHIE          error =   7.738%
Best 4 predictors:  DT        VSH_STB2  CALI      PHIE                 error =   9.524%
Best 3 predictors:  VSH_STB2  CALI      PHIE                           error =   6.548%
Best 2 predictors:  CALI      PHIE                                     error =  10.119%
Best 1 predictors:  PHIE                                               error =  48.810%
```

Increase number of input logs does not mean to improve results

CALI, VSH y PHIE are the best predictors for this data set

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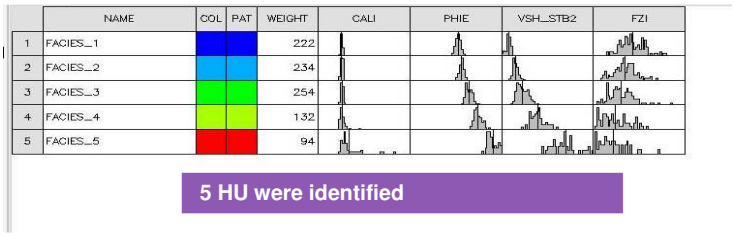
HYDRAULIC UNITS ZONATION



	NAME	COL	PAT	WEIGHT	CALI	PHIE	VSH_STB2	FZI
1	FACIES_1			222				
2	FACIES_2			234				
3	FACIES_3			254				
4	FACIES_4			132				
5	FACIES_5			94				

5 HU were identified

Hydraulic´s Unit	PHIE	VSH	FZI
1	0,24	0,08	8,47
2	0,22	0,16	6,84
3	0,18	0,24	6,11
4	0,13	0,4	4,79
5	0,04	0,7	4,24

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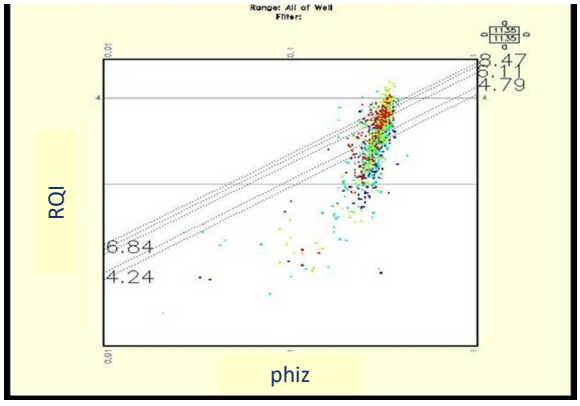
HYDRAULIC UNITS ZONATION



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HU PROPAGATION ACROSS THE WELL

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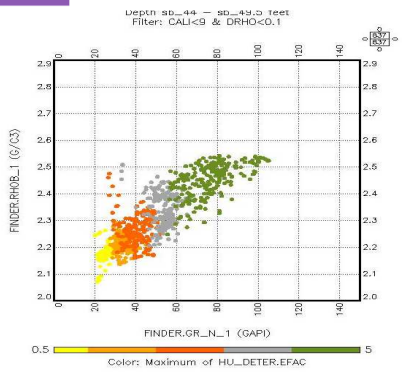
Crossplot to verify results consistency



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HU PROPAGATION ACROSS THE WELL

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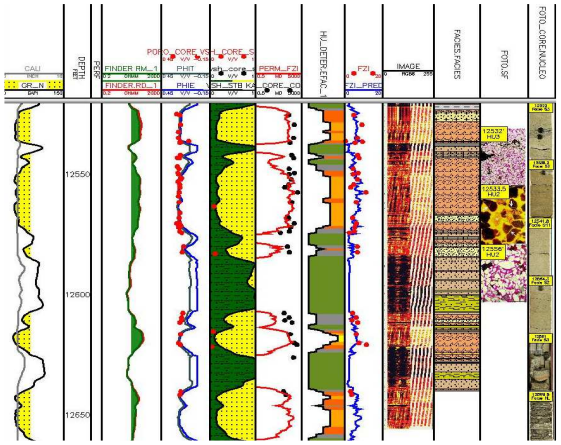
The methodology integrated all geological information available (subsurface core descriptions, microresistive image log, lithofacies, X-Ray diffraction, thin section and scanning electron microscope information

$$k = 1014 * FZI^2 * \left(\frac{\emptyset e^3}{(1-\emptyset e)^2}\right)$$



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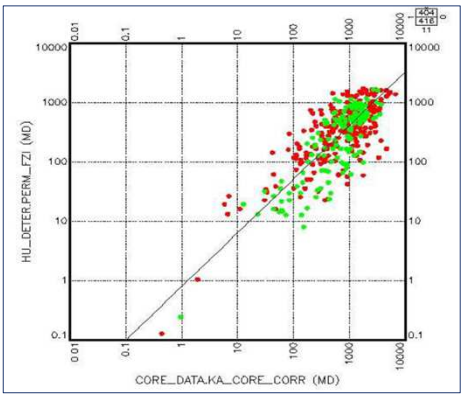
PERMEABILITY PREDICTION



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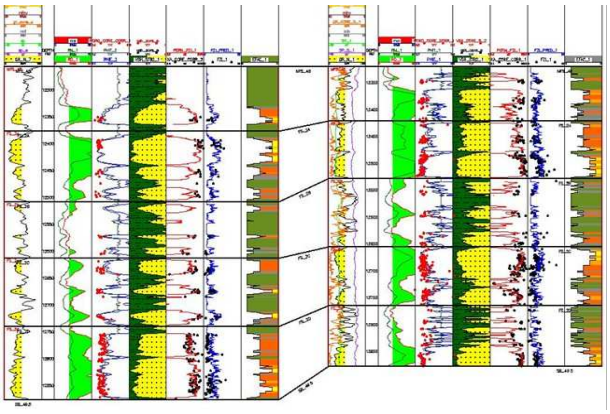
BLIND WELLS RESULTS

Wells drilled in 1960, poor log resolution



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NUMERICAL SIMULATION

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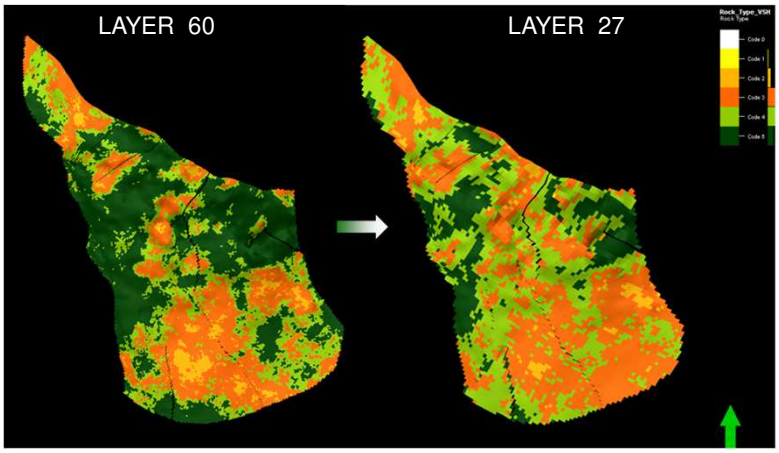
Rock types propagation

•78 layers model, with a size grid X,Y of 100x100 meters, total cells number 789750 and total actives cells 351181



HISTORY MATCH

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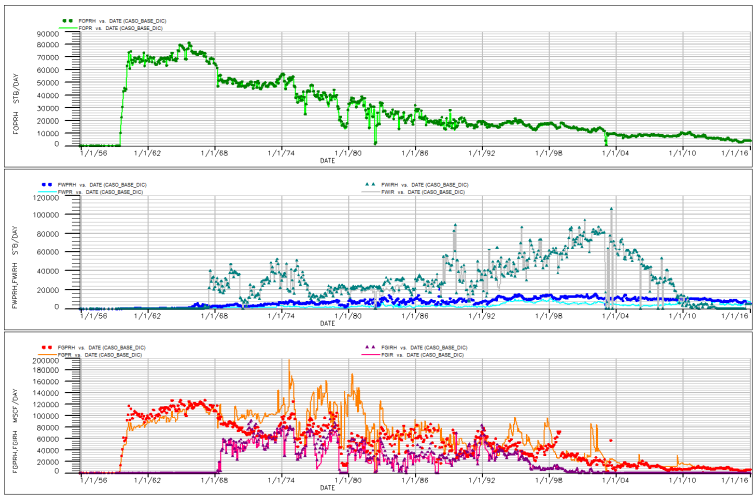
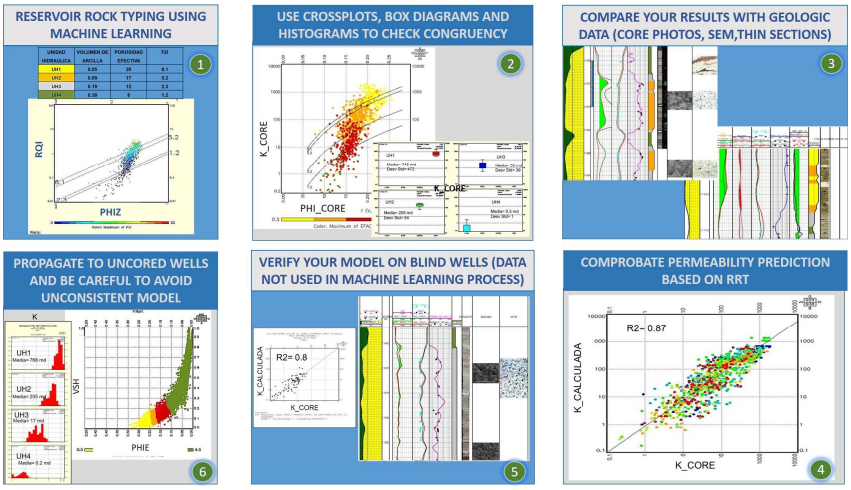
Oil

Water

Gas



SUMMARY



CONCLUSIONS

- Based on rigorous statistical approach and integration of all the geological information available it is possible to identify the optimal number of hydraulic unit in the reservoir under study.
- Accurate permeability and swir prediction is achieved by means of the application of the Flow zone indicator parameter.
- Reproduction of well performance behavior indicates that results obtained in this study can be used as input for numerical simulation purposes.

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"All models are wrong, but some are useful"

George Box