

Permeability Model using Minifracture Analysis in Tight Sands of Mature Fields*

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Abstract

The permeability is one of the most difficult parameters to estimate in the tight sands reservoirs of mature fields of the Peruvian Northwest. Most of the Build-Up Tests (BU) were ineffective for estimating permeability because they did not reach radial flow. Since their values are in the order of 0.01 to 1 md, all reservoirs are stimulated with hydraulic fracturing. In these operations, injection test time usually ends up at fracture closure pressure, making difficult the use of traditional method of After Closure Analysis (ACA) for dealing with permeability. This study shows the development of a permeability model based on a Minifrac Analysis Methodology in Tight Sands Reservoirs of the Peruvian Northwest.

Minifrac Analysis is a useful alternative because it is performed for each reservoir stage and estimates permeability using before and during fracture closure data. The methodology is based on the application of two analysis methods. Modified Mayerhofer Method (Mayerhofer, Valko and Economides, 1999) uses available information before fracture closure. Empirical Correlation Method (Barree, 2007) uses information during fracture closure. Both methods calculate permeability as a function of the closure pressure, which is initially estimated using the G function. For developing the model, 130 Minifrac tests were analyzed. These analyses showed that for a closure pressure, both methods converge in one permeability value. The results have been validated with some data from BU, K-Phi laws and facies distribution maps. All these allowed defining a clear permeability trend for each reservoir analyzed. The results obtained have led complement the high resolution stratigraphic model and developed a Permeability Model in the study area. This methodology can be applied for permeability characterization in fields with similar characteristics, optimizing the use of information generated during Minifrac.

References Cited

- Barree, R.D., V.L. Barree, and D.P. Craig, 2007, Holistic fracture diagnostics: SPE 107877.
- Ceccarelli, R.L., A. Ciucă, and M. Tambini, 2009, New Methodology of Mini-fall-off test to optimize hydraulic fracturing in unconventional reservoir: SPE 122326.
- Craig, D.P., M.J. Eberhard, and R.D. Barree, 2000, Adapting high permeability leakoff analysis to low permeability sands for estimating reservoir engineering parameters: SPE 60291.
- Mayerhofer, M., P.P. Valko, and M.J. Economides, 1999, Fluid-leakoff delineation in high permeability fracturing: SPE, v. 14/2, p. 110.
- Mayerhofer, M., 2012, DFIT (Diagnostic Fracture Injection Test): SWPLA, Texas.
- Valko, P., and M. Economides, 1998, Methodology of fluid leakoff analysis in high-permeability fracturing: SPE 39476.

Permeability Model using MiniFrac Analysis in Tight Sand of Mature Fields

**GTW – 2015
Lima, Peru**

Speaker: José Pajuelo

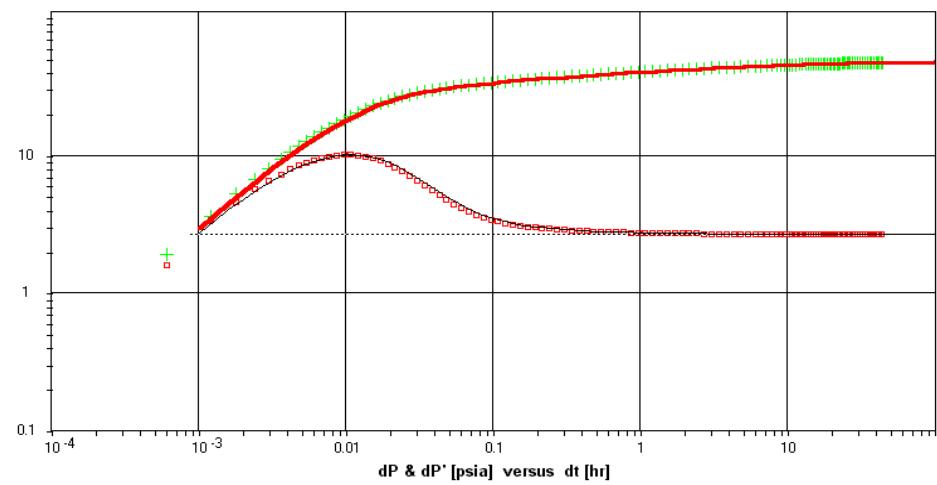
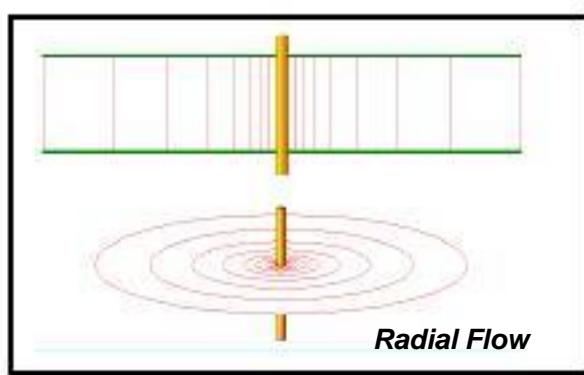
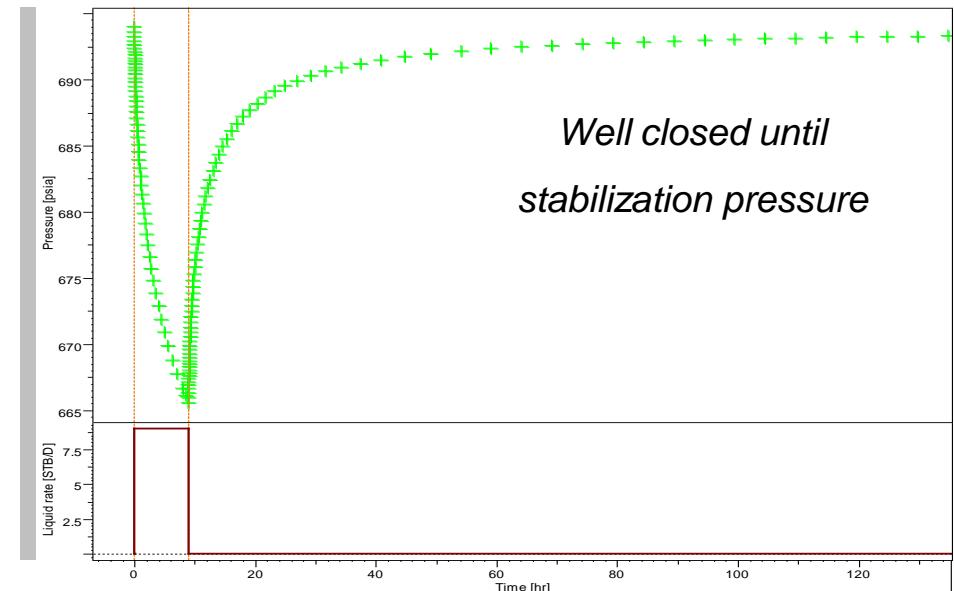
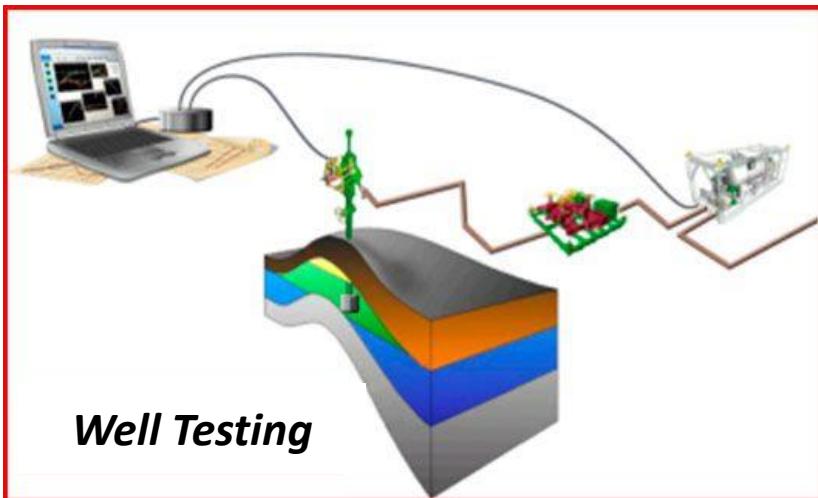
**Coauthor (s): Grethel Moreyra
Diego Escobedo**

Problematic

Permeability

- ✓ Mature Fields
- ✓ Low Quality
- ✓ High percentage of ineffective Pressure Testing

Conventional Method

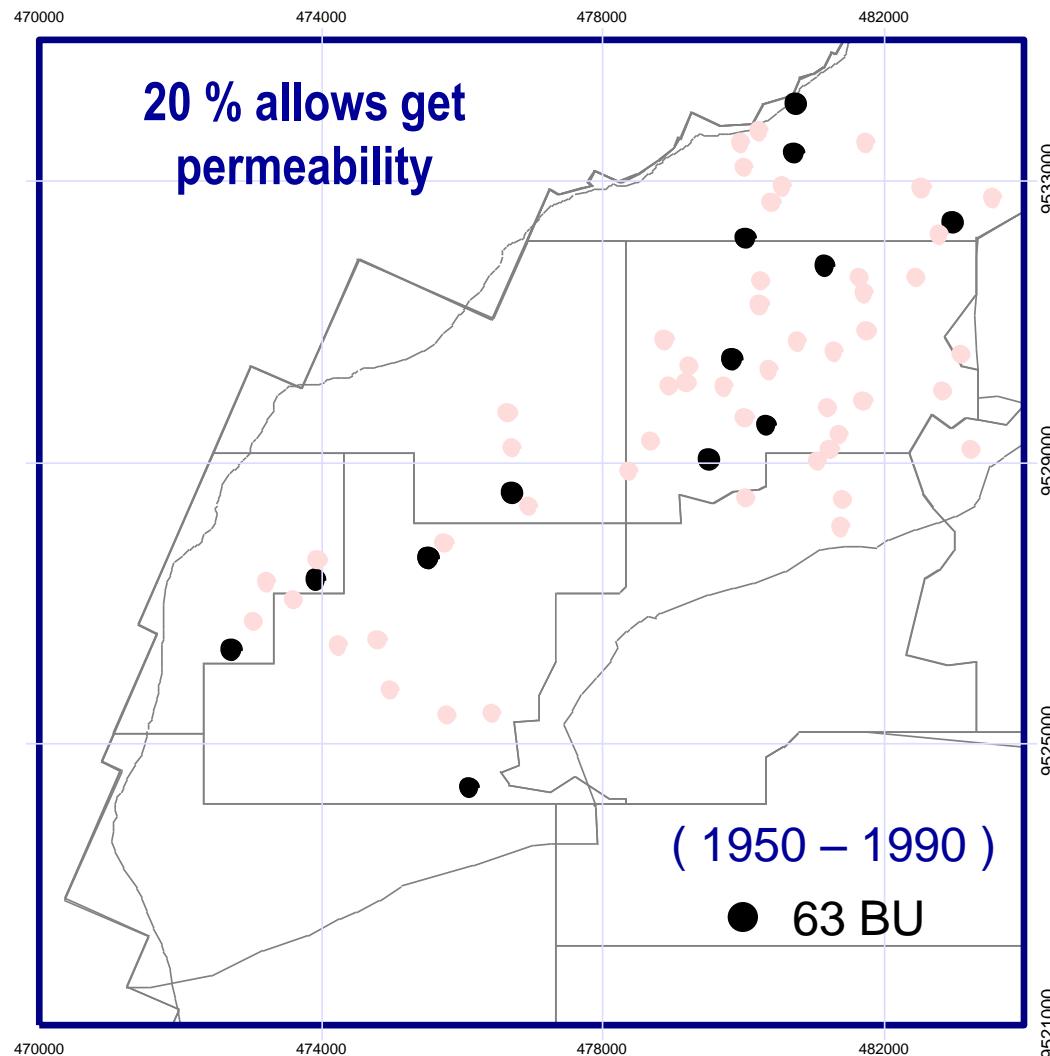


Conventional Method

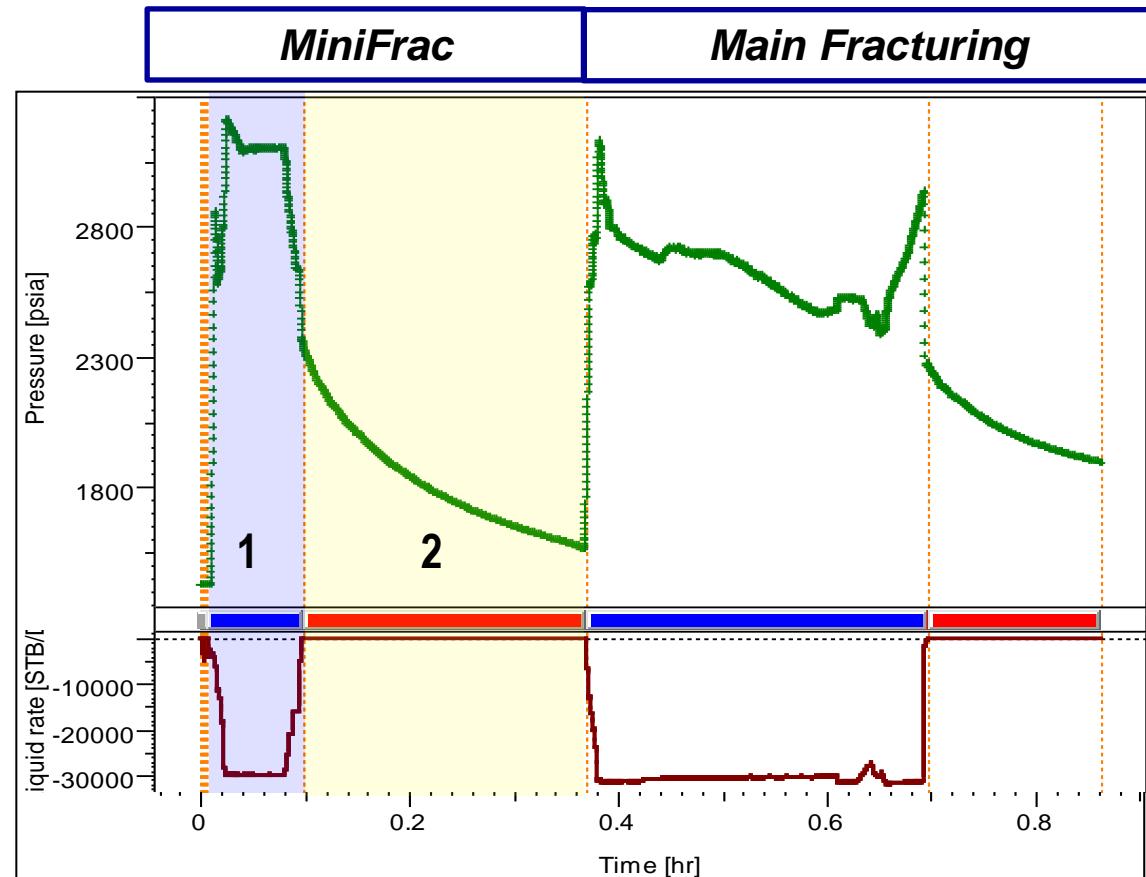
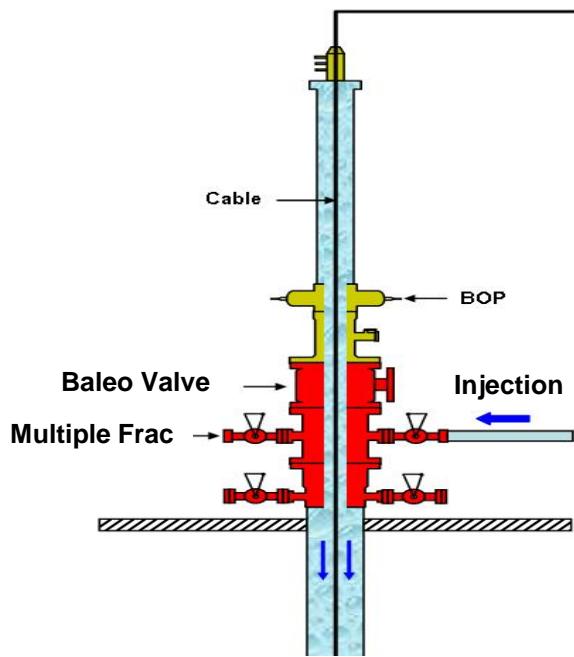


Build Up

13 Wells



Fracturing Data



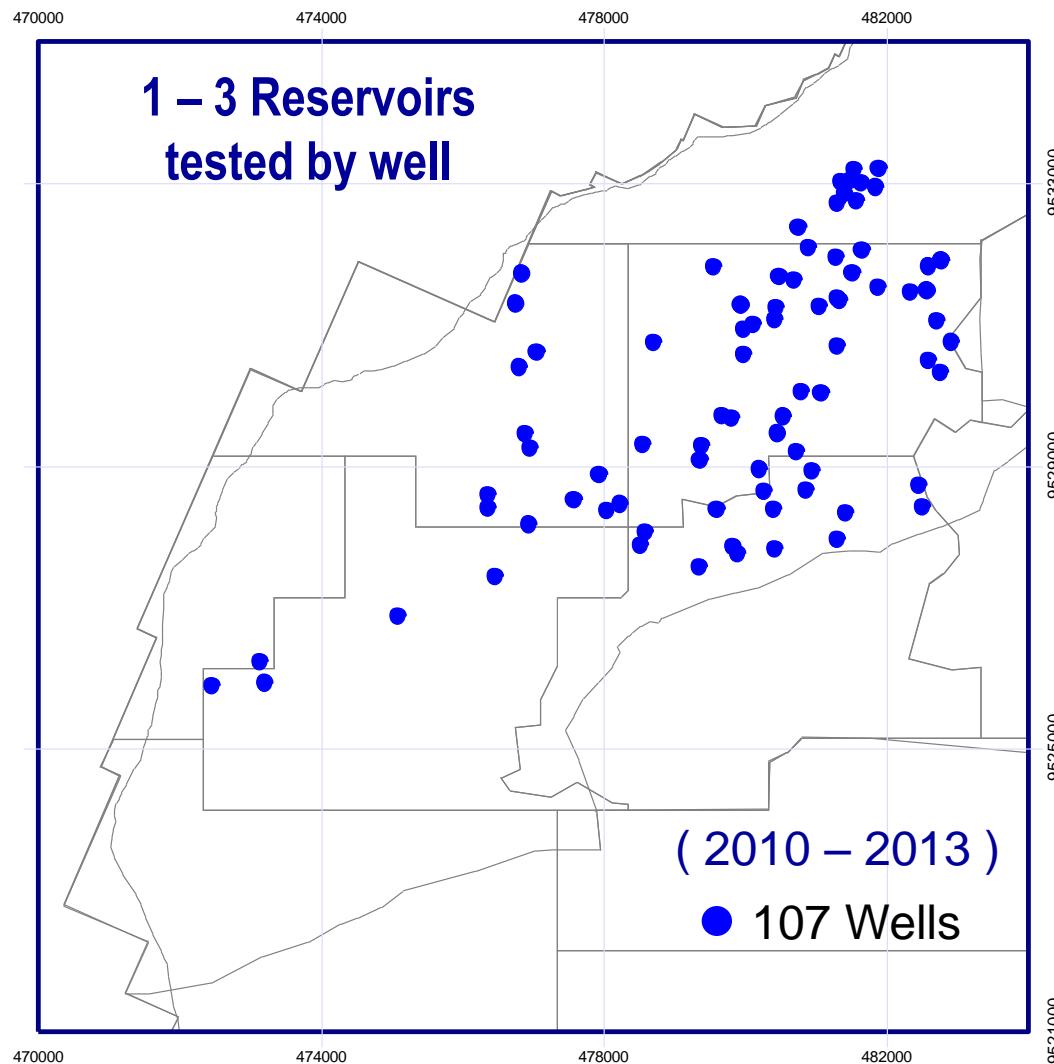
1. Brine Injection **Volume <30 – 50 bbl>**
2. Decline Period **Time <20 – 40 min>**

Fracturing Data



MiniFracs

107 Wells



Index

1 *CONTEXT*

2 *OBJECTIVE*

3 *THEORETICAL BASES*

4 *ANALYSIS AND RESULTS*

5 *CONCLUSIONS*

Context

1

CONTEXT

OBJECTIVE

THEOREICAL BASES

ANALYSIS AND RESULTS

CONCLUSIONS

✓ **Analyze**

Ineffective BU

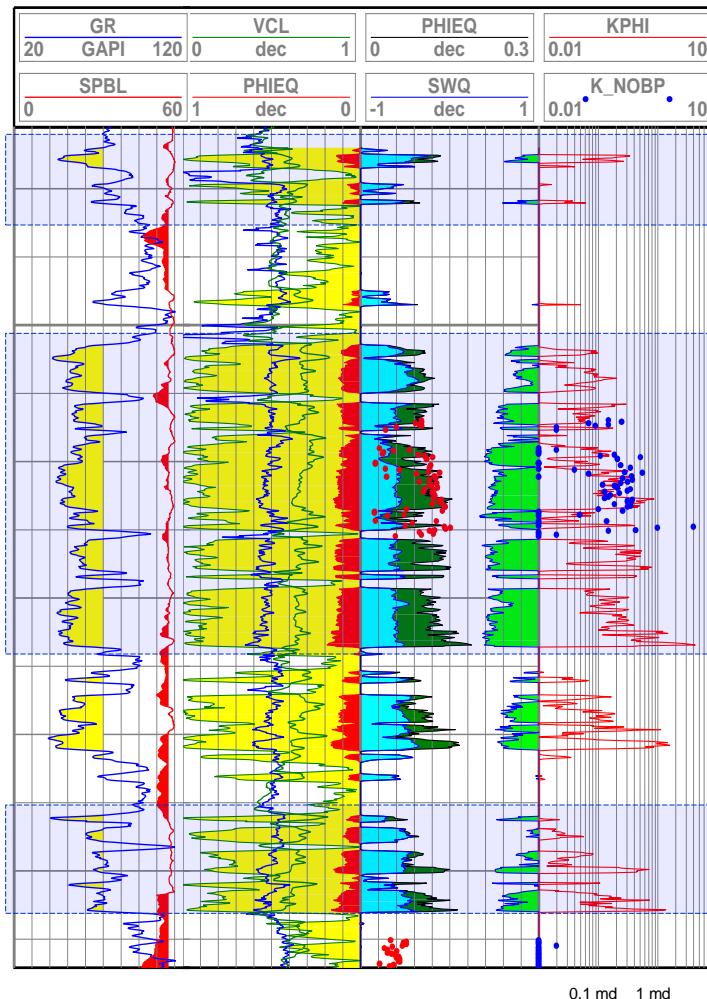
✓ **New**

Alternative

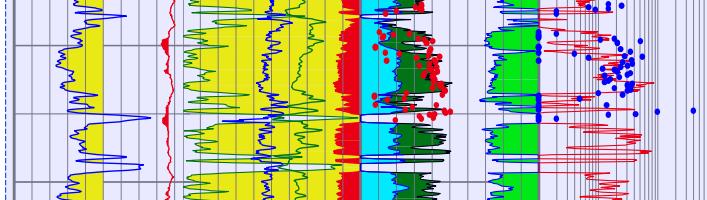
BU Analysis

Cores Permeability Data

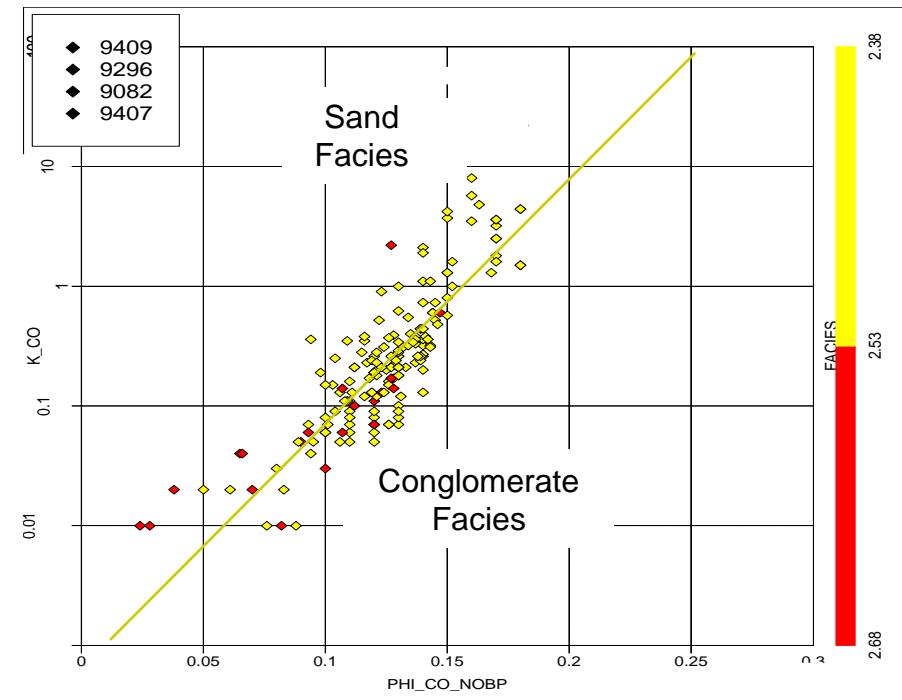
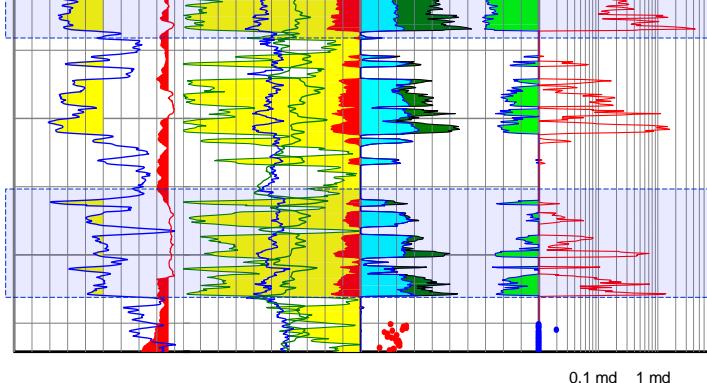
A



B



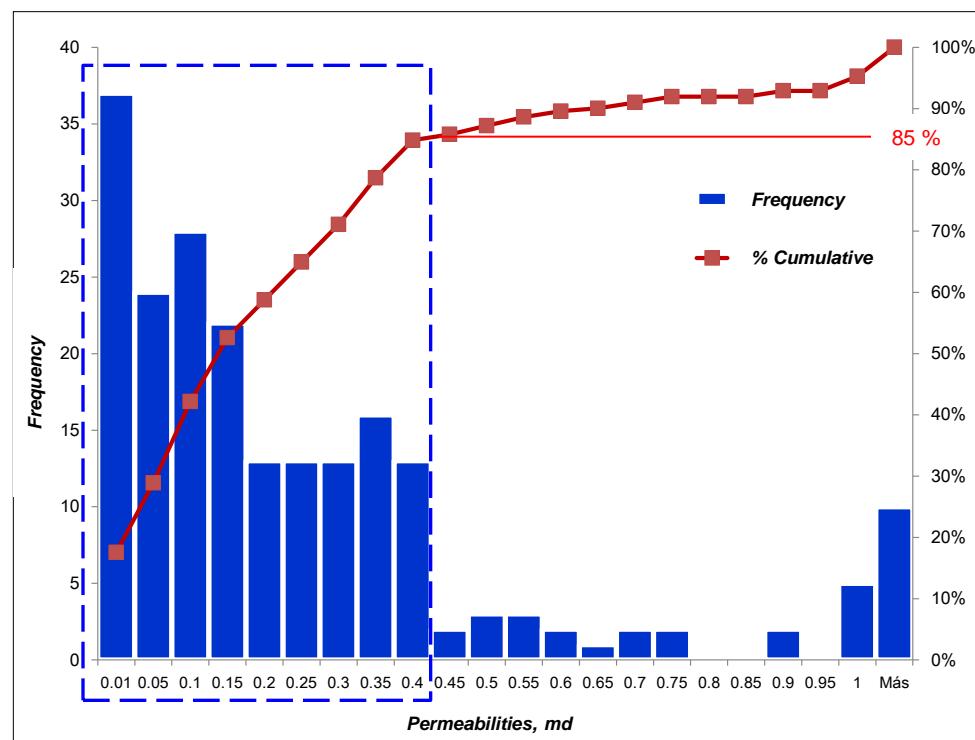
C



K_{Core} VS $\Phi_{\text{Core - NOBP}}$

BU Analysis

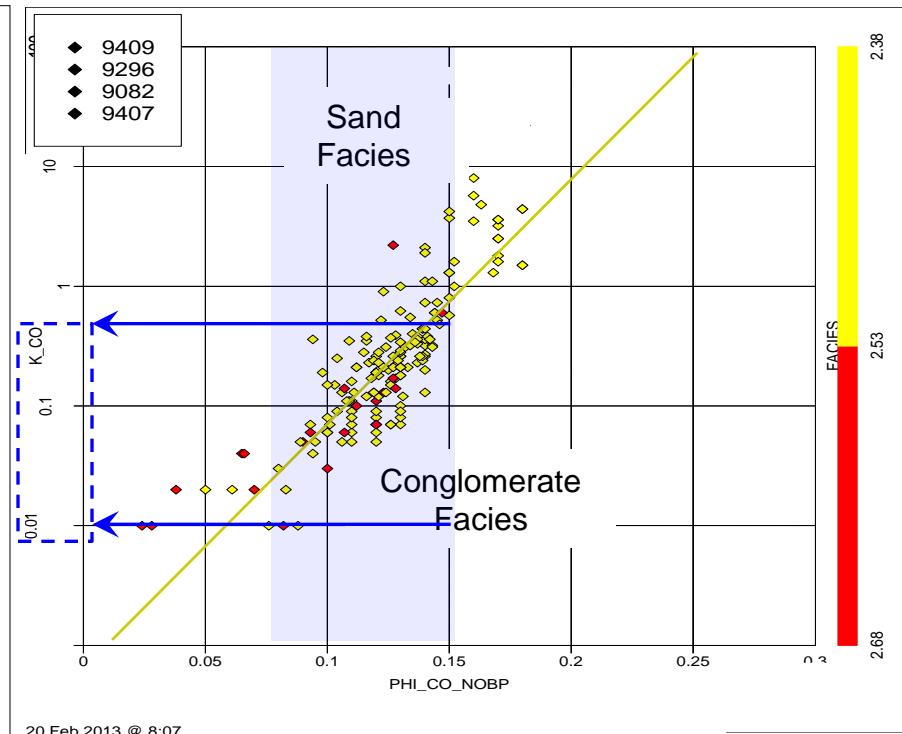
Cores Permeability Data



Permeabilities Histogram

85 % Permeabilities: 0.01 – 0.4 md

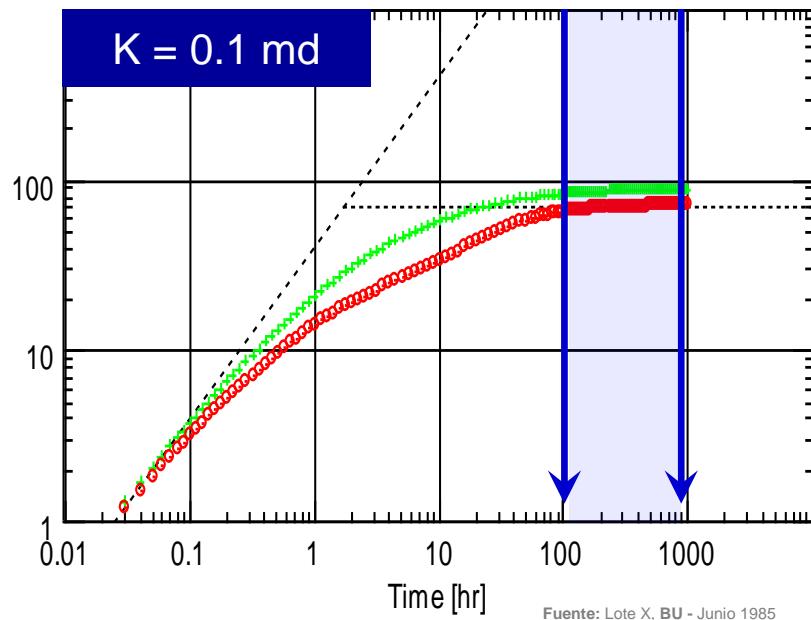
15 % Permeabilities: 0.4 – 10 md



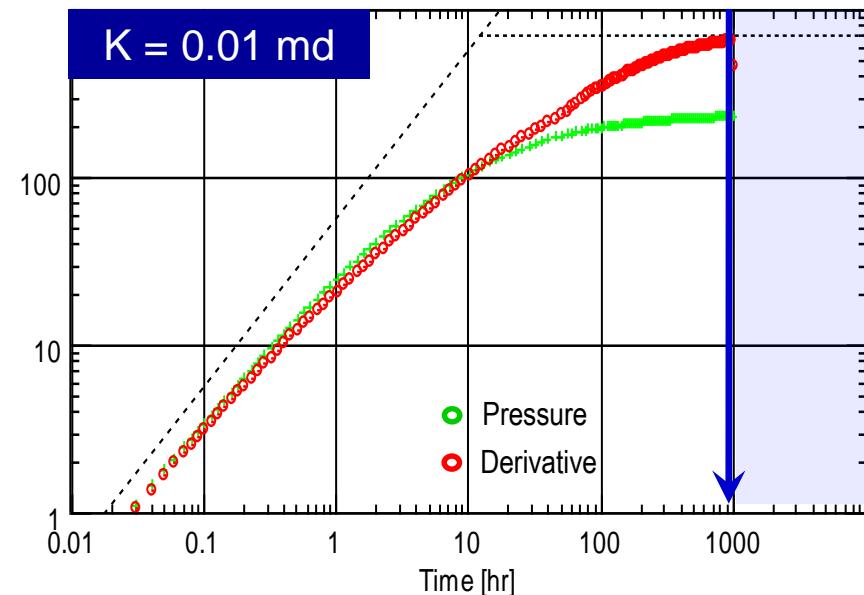
K Core VS Φ Core - NOBP

$0.01 \text{ md} \leq \text{Absolute Permeability} \leq 0.4 \text{ md}$

BU Analysis



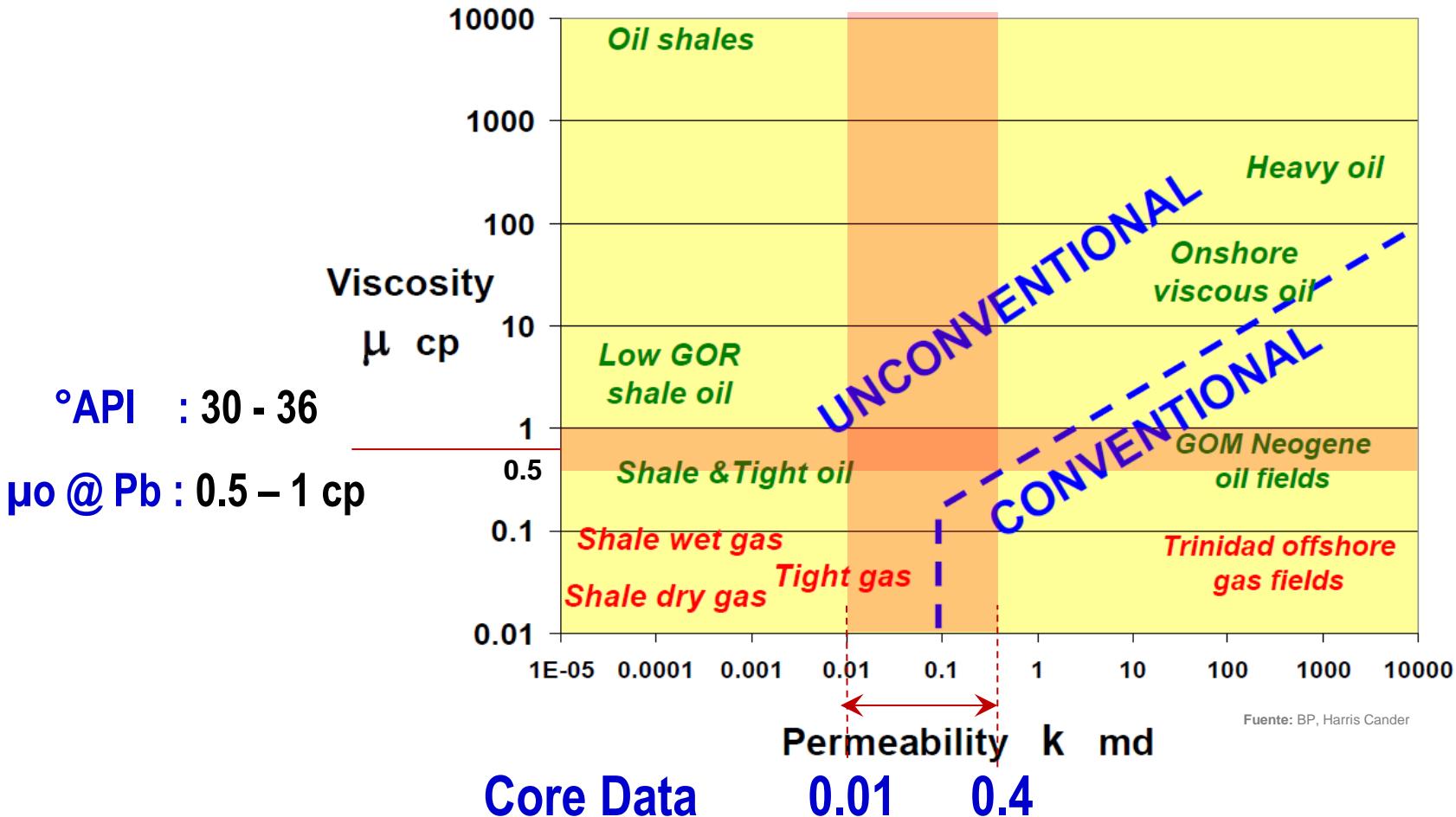
Time to observe stabilization period
 $<100, 1000 \text{ hrs}>$ (4 - 42 days)



Time to observe stabilization period >
1000 hrs (42 days)

Reservoirs Clasification

Unconventionals can be defined on a graph of viscosity (μ) vs. permeability (k)



Objective

1

CONTEXT

2

*OBJECTIVE**THEOREICAL BASES**ANALYSIS AND RESULTS**CONCLUSIONS*

✓ **MiniFrac**

Permeability

✓ **Trend models by
reservoir**

Theoretical Bases

1 CONTEXT

2 OBJECTIVE

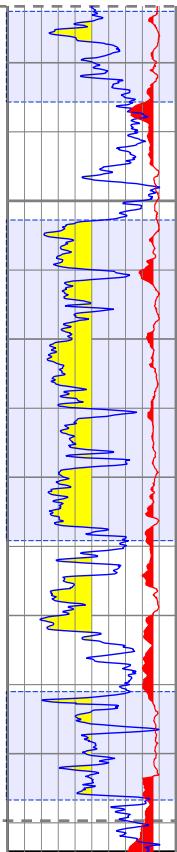
3 THEOREICAL BASES

ANALYSIS AND RESULTS

CONCLUSIONS

New Focus: MiniFrac Test

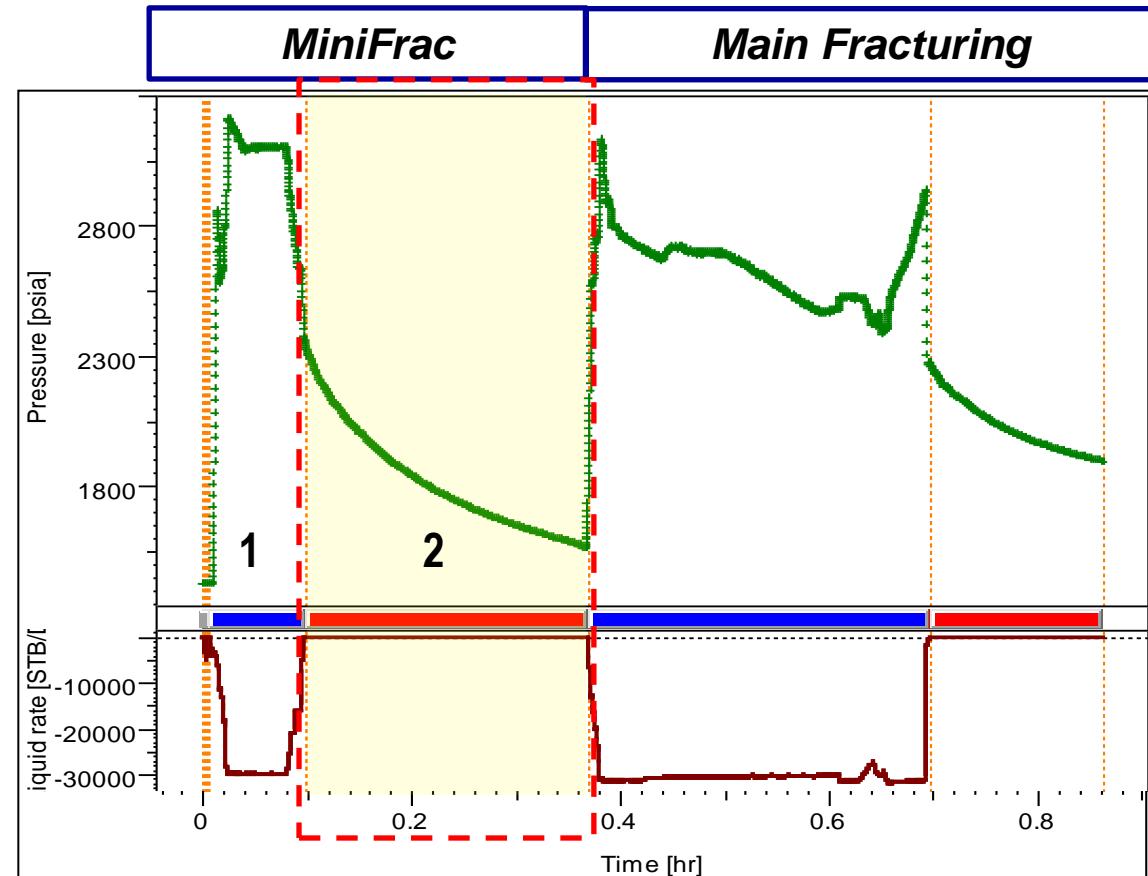
MiniFrac Test



A

B

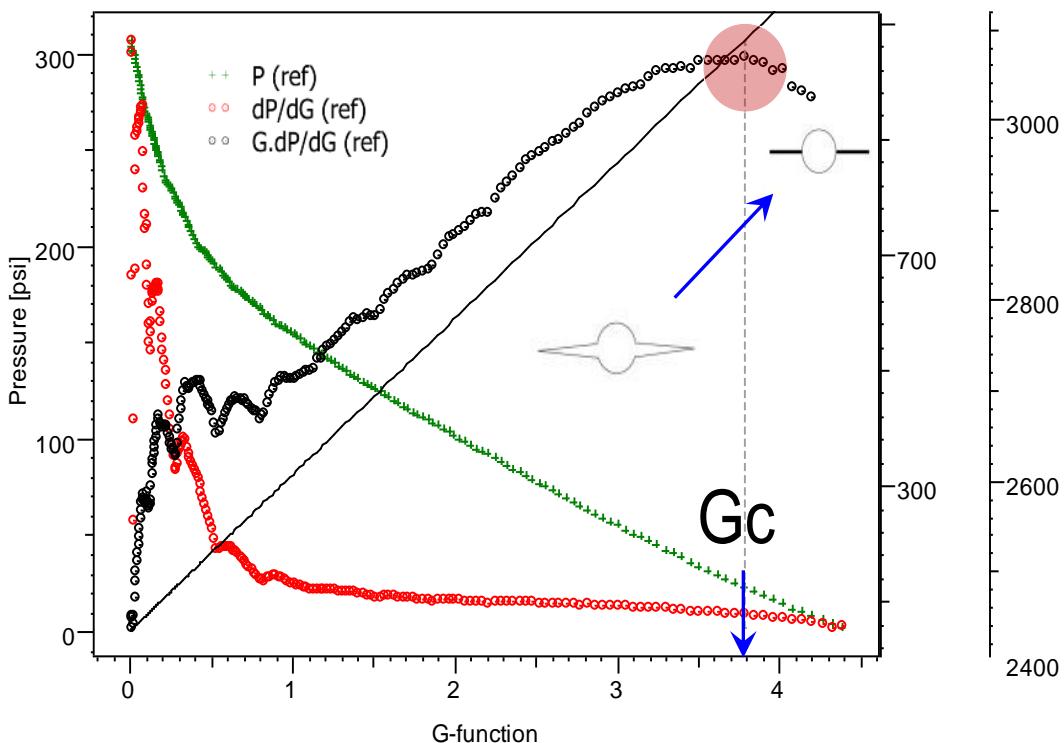
C



1. Brine Injection Volume <30 – 50 bbl>
2. Decline Period Time <20 – 40 min>

G Function Chart

Function G: Diagnostic Chart



- ✓ Dimensionless function time.
- ✓ Its used to identify the Closure Pressure.

$$G(\Delta t_D) = \frac{4}{\pi} (g(\Delta t_D) - go)$$

$$g(\Delta t_D) = 1.3769 + 1.9124 \Delta t_D - 1.18519 \Delta t_D^{1.5} + 0.37185 \Delta t_D^2 + 0.05267 \Delta t_D^{2.5} - 0.075746 \Delta t_D^3$$

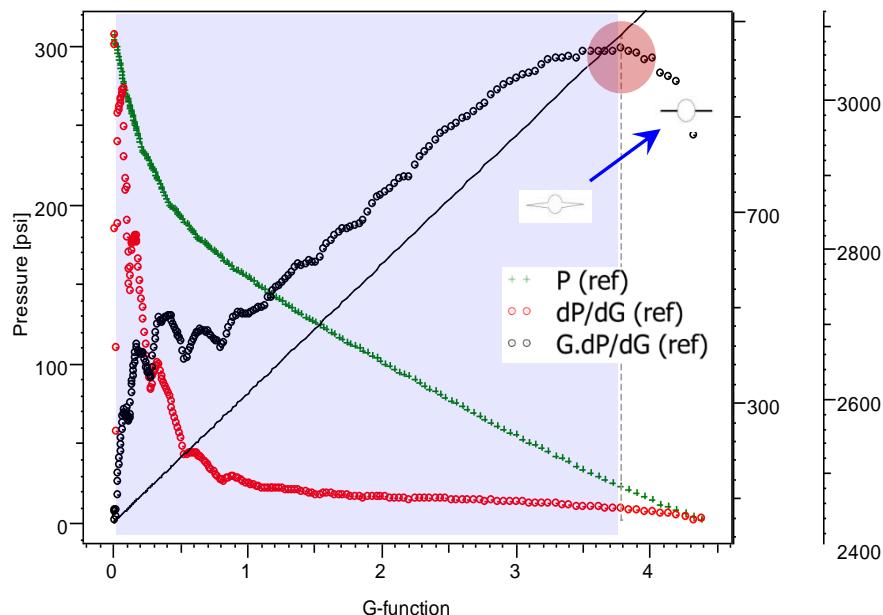
Fuente: Valko P; Economides M SPE 39476 Methodology of Fluid Leakoff Analysis in High-Permeability Fracturing.
Texas, 1998

$$go(\alpha) = 1.377 \quad \Delta t_D = \frac{t - t_p}{t_p}, \quad t_p = \text{pumping time}$$

Interpretation Methods

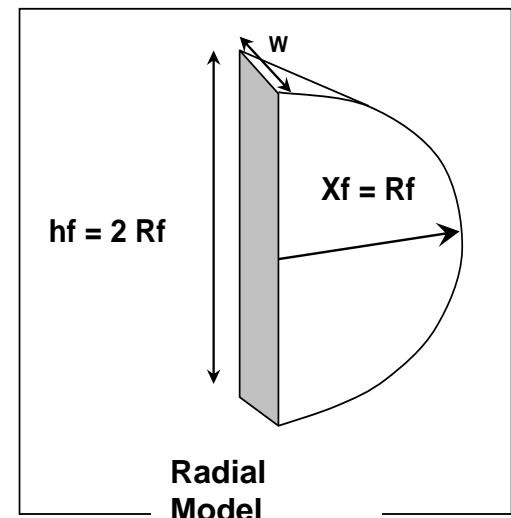
1. Modified Mayerhofer Method (M. Mayerhofer, Ehlig-Economides, 1999)

- ✓ Pressure data before the close fracture



Assumptions

- ✓ Homogeneous Reservoir
- ✓ Fracture Radial Geometry

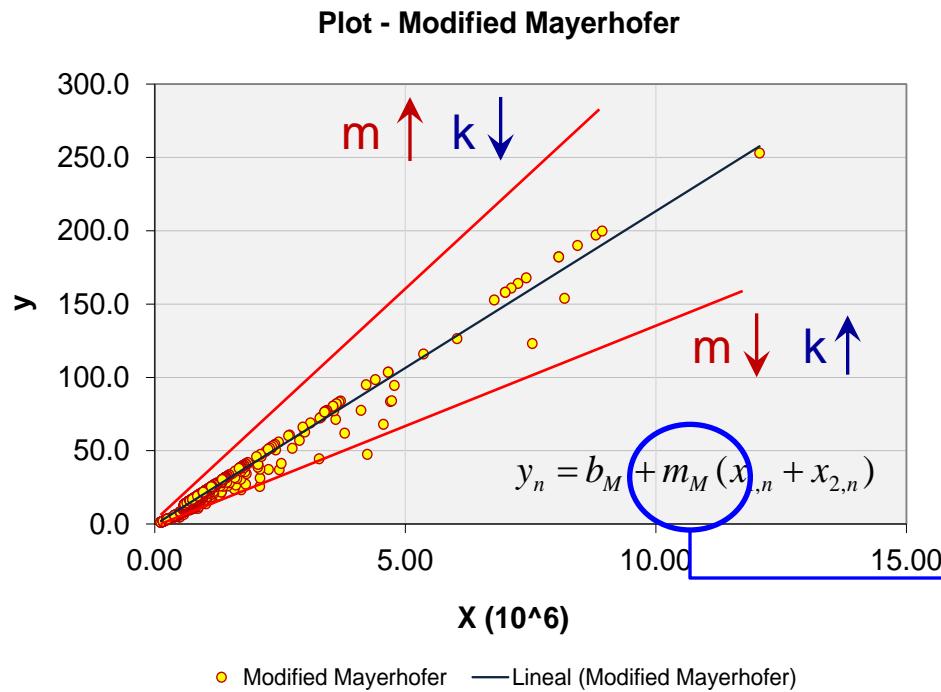


Interpretation Methods

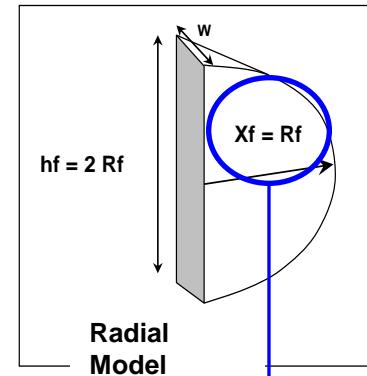
1. Modified Mayerhofer Method (M. Mayerhofer, Ehlig-Economides, 1999)

Input Data

ϕ	Porosity
c_t	Total Compressibility
μ	Fluid Viscosity
V_i	Injected Volume
t_e	Pumping time
P_c	Closure Pressure
P_r	Reservoir Pressure
E'	Young Dynamic Module
v	Poisson Coeficient



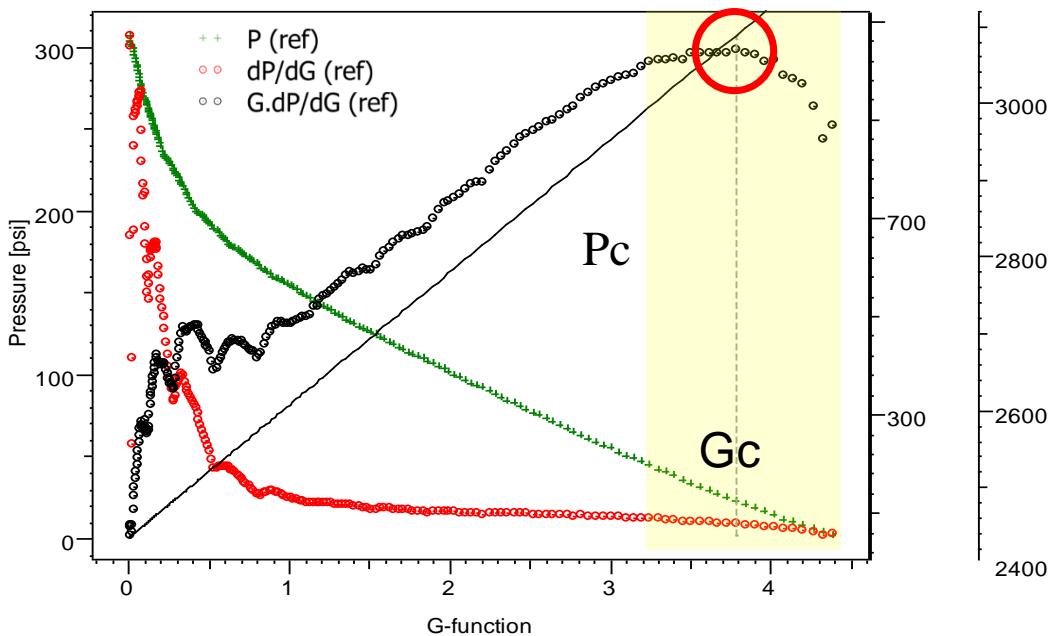
Fuente: Mayerhofer, M. DFIT (Diagnostic Fracture Injection Test). SWPLA. Texas, 2012
Adaptado: A un ensayo de MiniFrac en el Lote X



$$k = \left(\frac{R_f}{m_M} \right)^2$$

Interpretation Methods

2. Empirical Correlation Method (V. L. Barree, 2007)



Fuente: Ceccarelli, r. L.; Ciucia, a.; Tambini, m. SPE 122326 New Methodology of Mini-fall-off test to Optimize Hidraulic Fracturing in Unconventional Reservoir. Sheveningen, 2009

$$k = \frac{0.0086 \mu_f \sqrt{0.01 p_z}}{\phi c_t \left(\frac{G_c E r_p}{0.038} \right)^{1.96}}$$

Donde:

k = Effective Permeability, md

G_c = G Function value at the closure point, dimensionless

P_z = Net Pressure (ISIP – Pclosure)

E = Young Module, MMpsi

r_p = Storage ratio

Fuente: M.; Barree, R. SPE 60291 Adapting High Permeability Leakoff Analysis to Low Permeability Sands for Estimating Reservoir Engineering Parameters. Denver, 2000

Analysis and Results

1

CONTEXT

2

OBJECTIVE

3

THEOREICAL BASES

4

*ANALYSIS AND RESULTS**CONCLUSIONS*

✓ Interpretation

✓ Results

✓ Validation

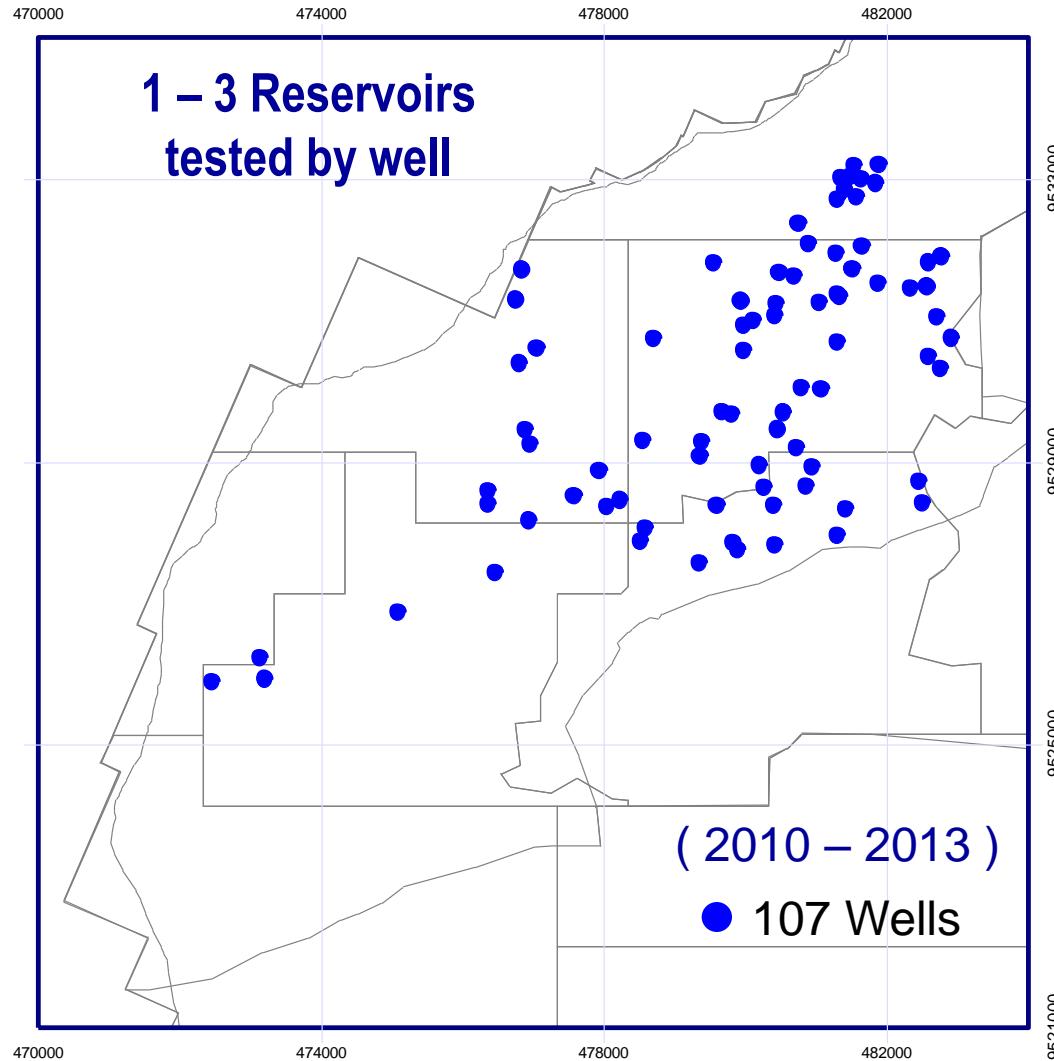
Fracturing Data



Block X
470 Km²

MiniFracs

107 Wells



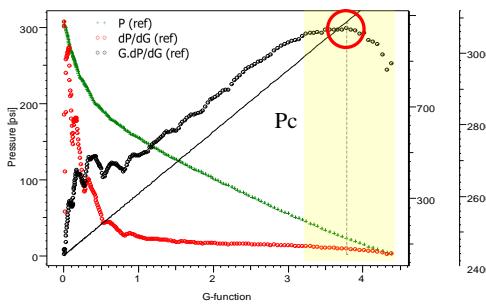
WorkFlow

Input Data

- ✓ Reservoir Characterization
- ✓ Fluid Injected Characterization

K, md

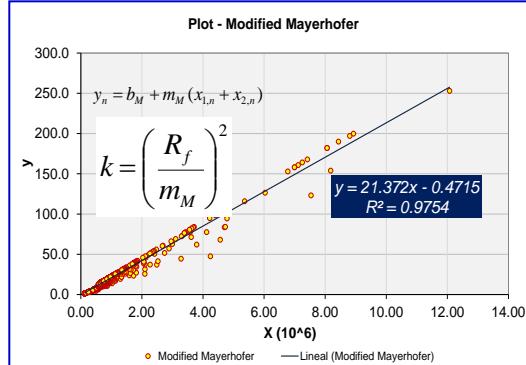
**G Function
Chart**



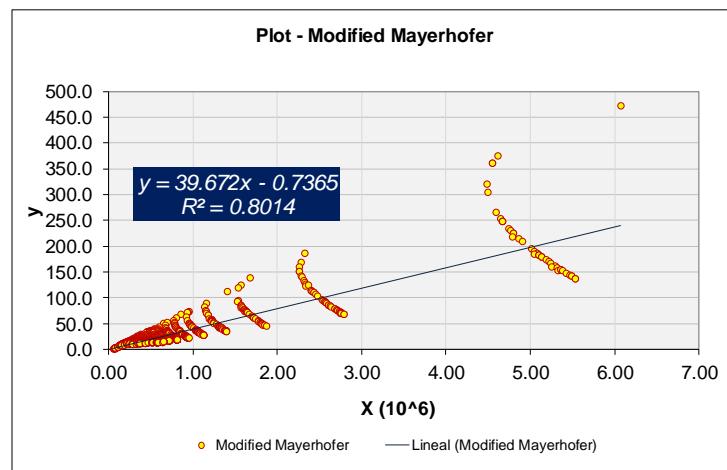
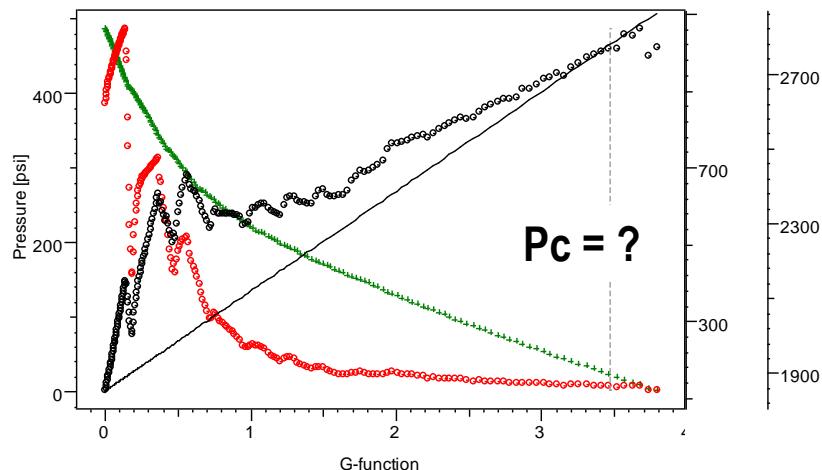
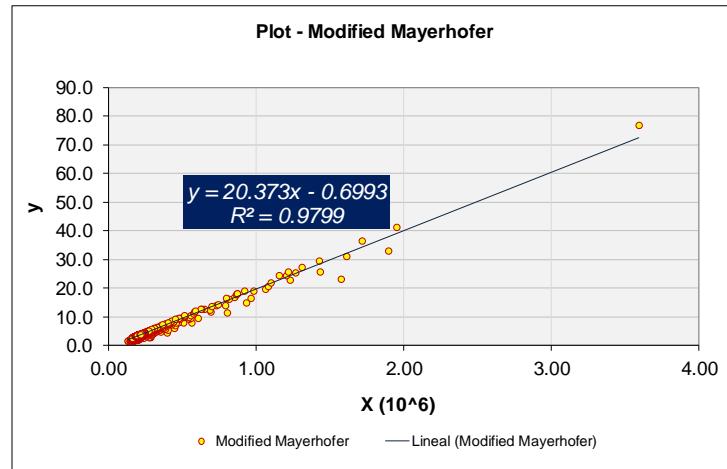
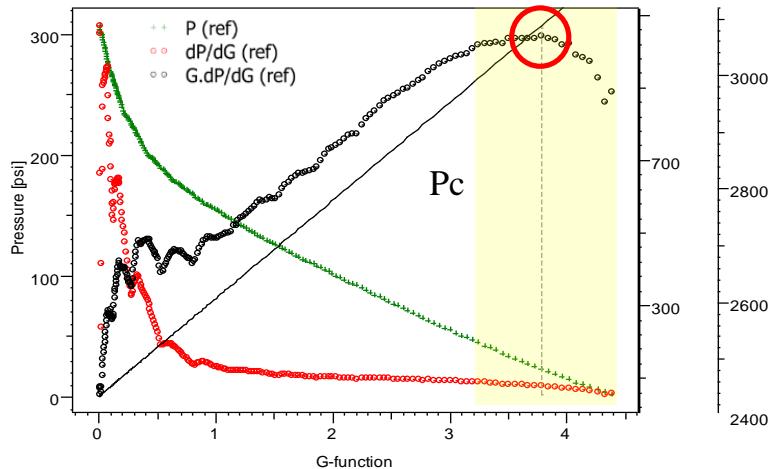
**Empirical
Correlation**

$$k = \frac{0.0086 \mu_f \sqrt{0.01 p_z}}{\phi c_t \left(\frac{G_C E r_p}{0.038} \right)^{1.96}}$$

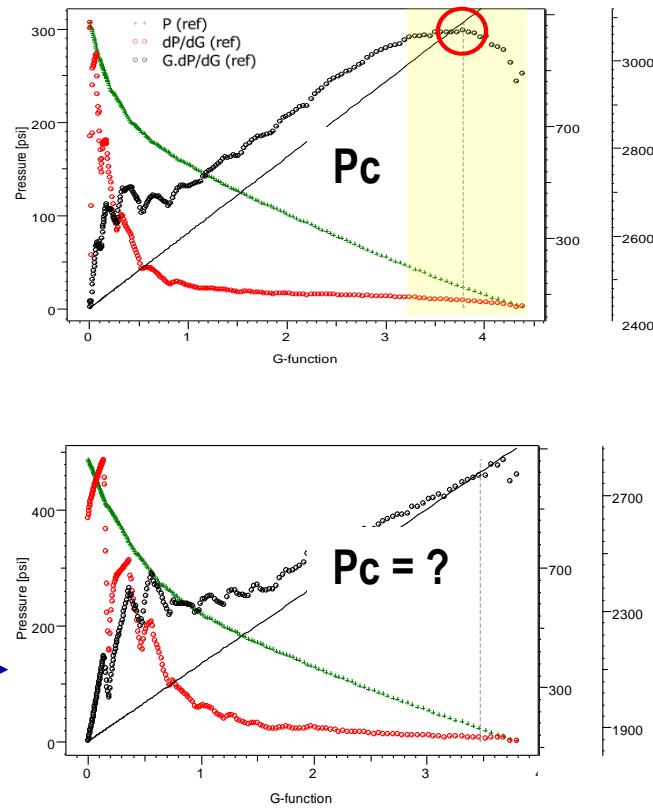
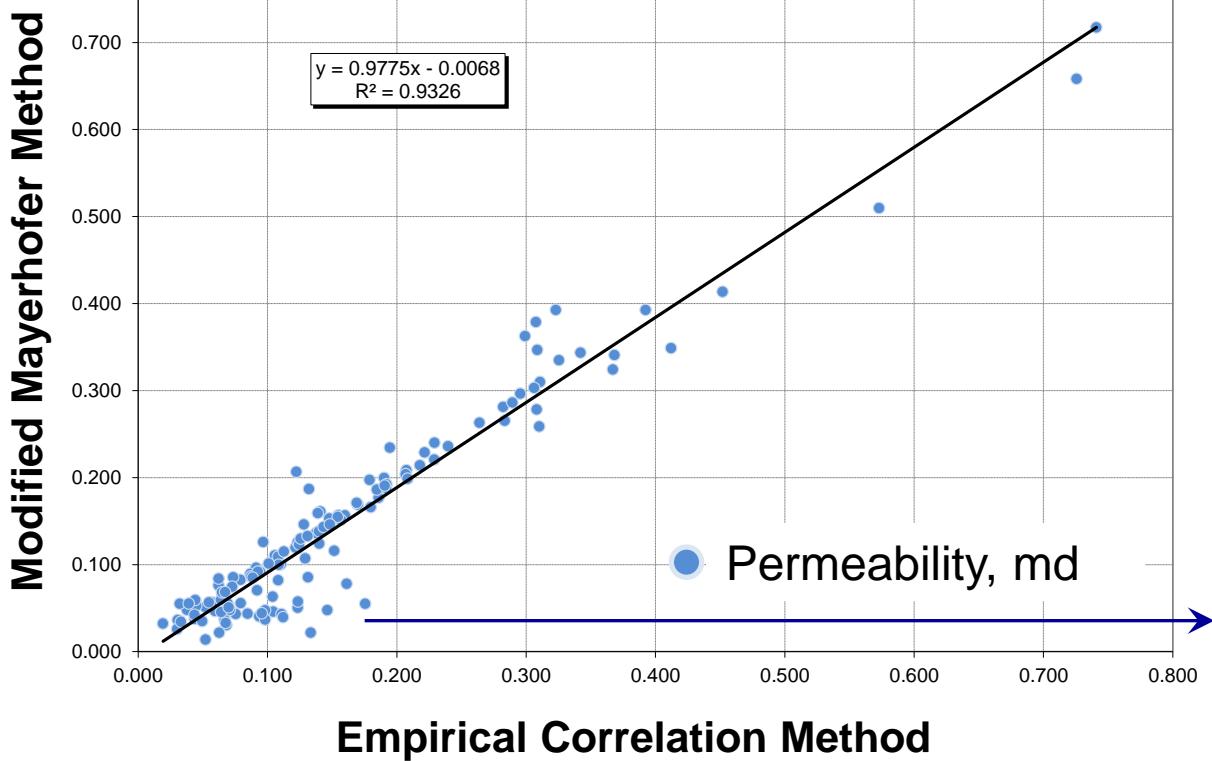
**Modified
Mayerhofer**



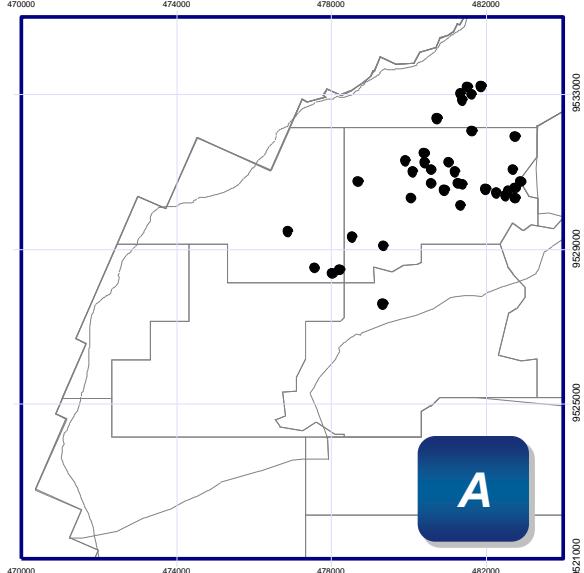
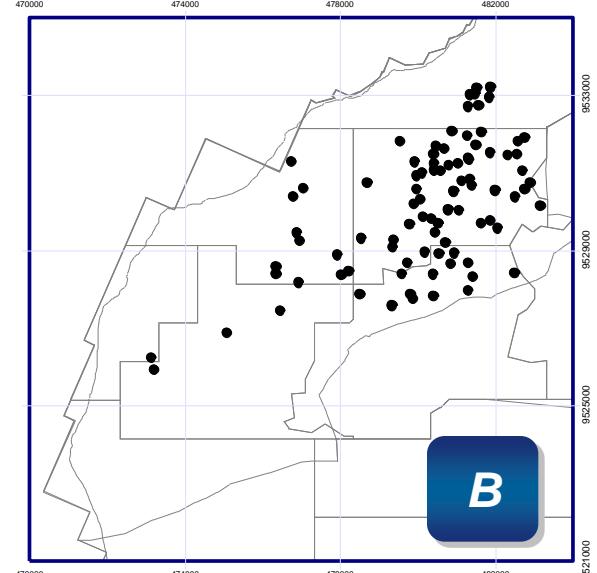
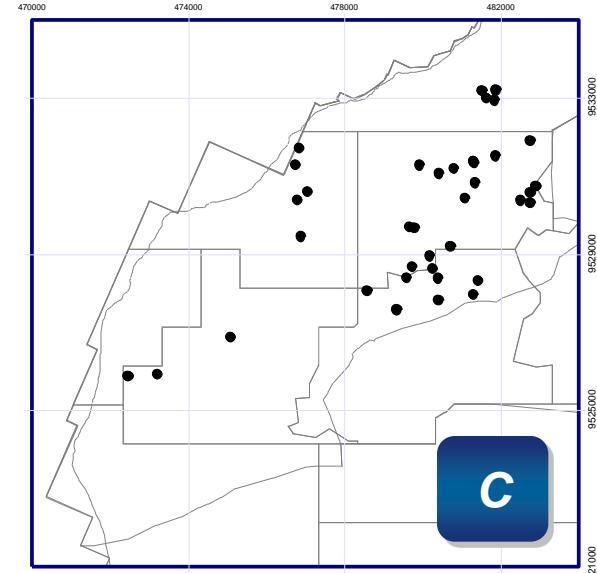
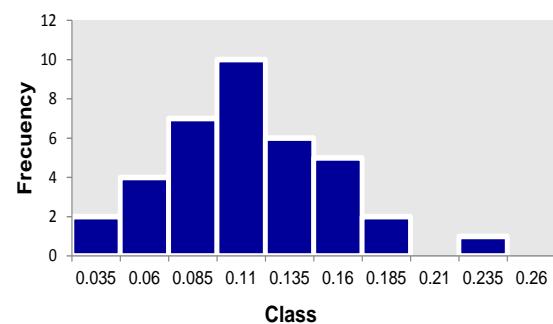
Results Interpretation



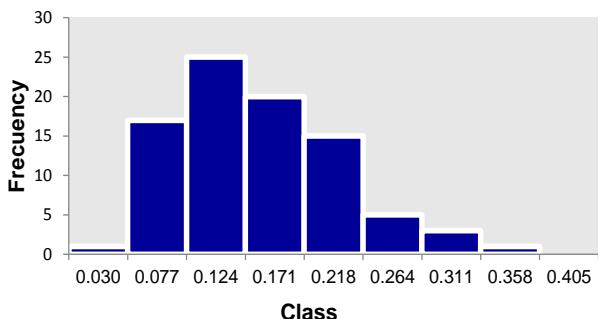
Results Interpretation



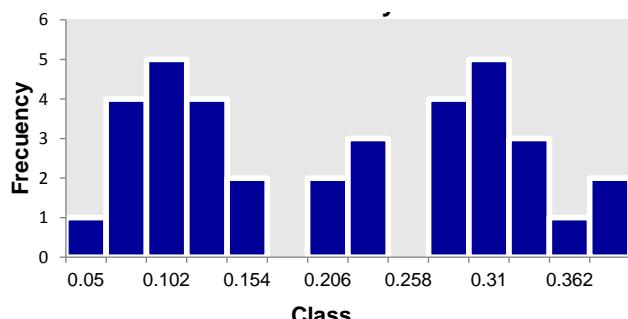
Permeabilities by Reservoir

**A****B****C**

Average	0.101
Standard Desviation	0.0434
Count	37



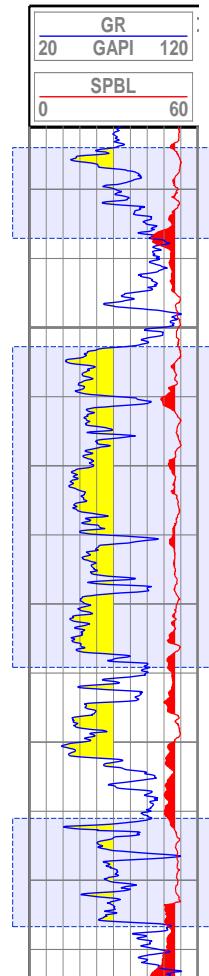
Average	0.141
Standard Desviation	0.0806
Count	89



Average	0.092
Standard Desviation	0.0300
Count	16

Average	0.312
Standard Desviation	0.1068
Count	22

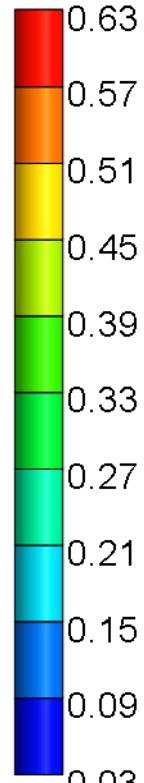
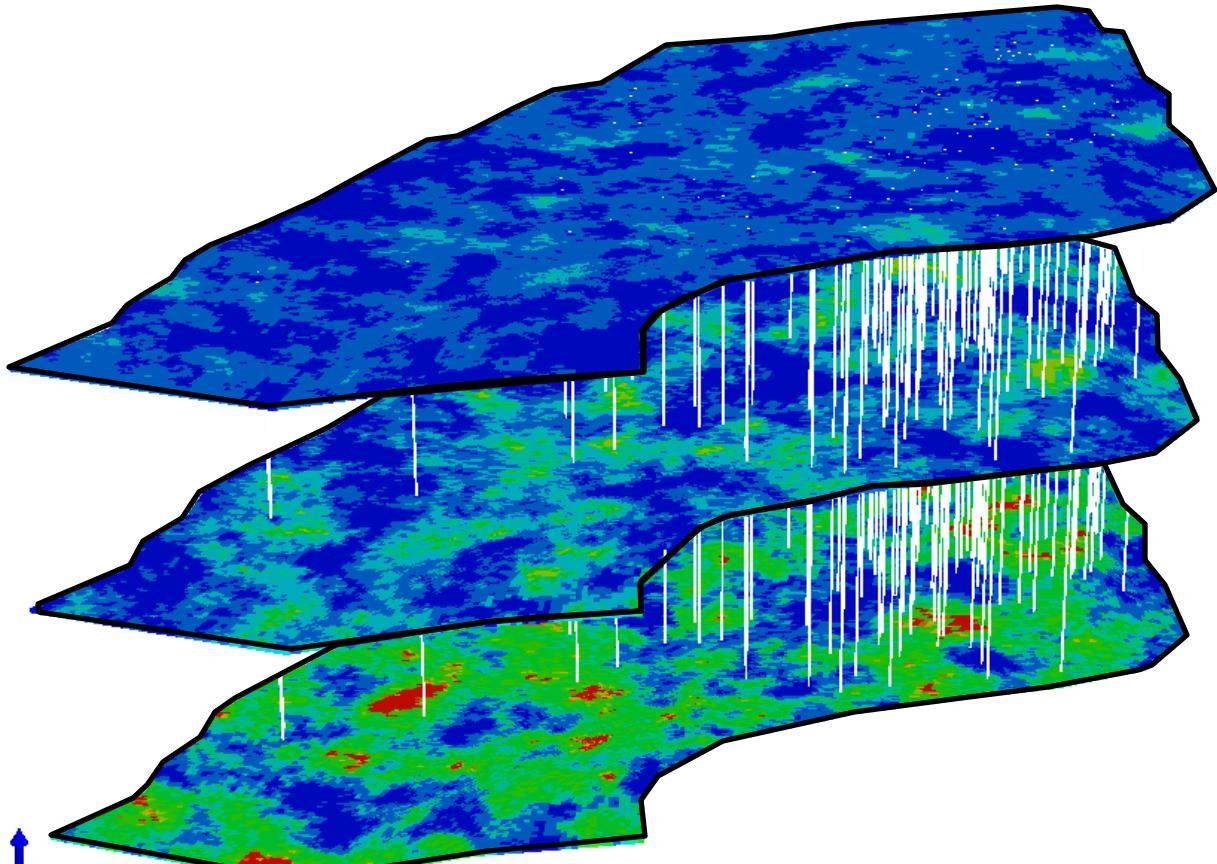
Permeabilities Model



A

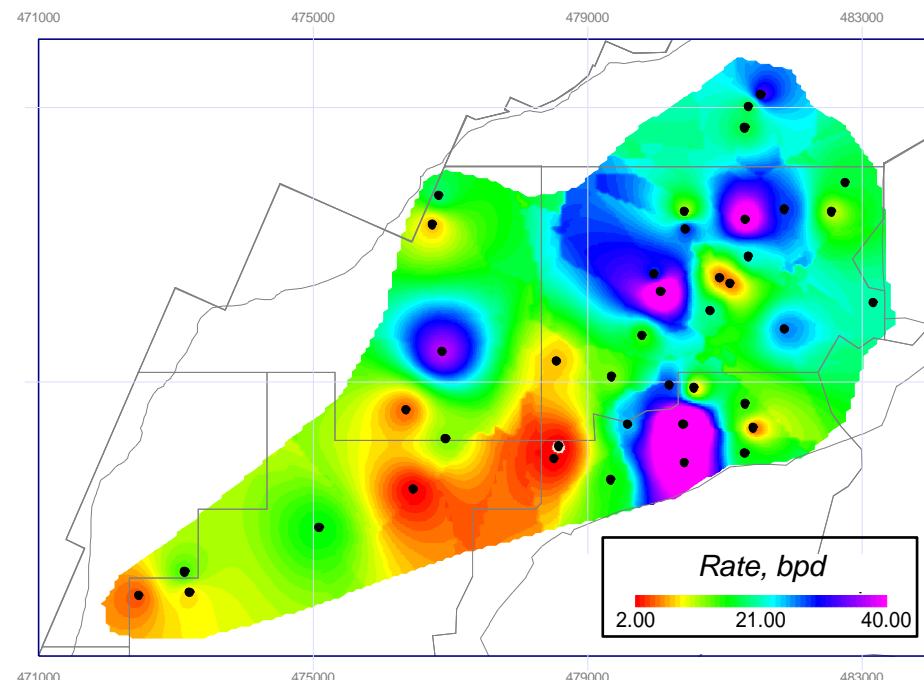
B

C

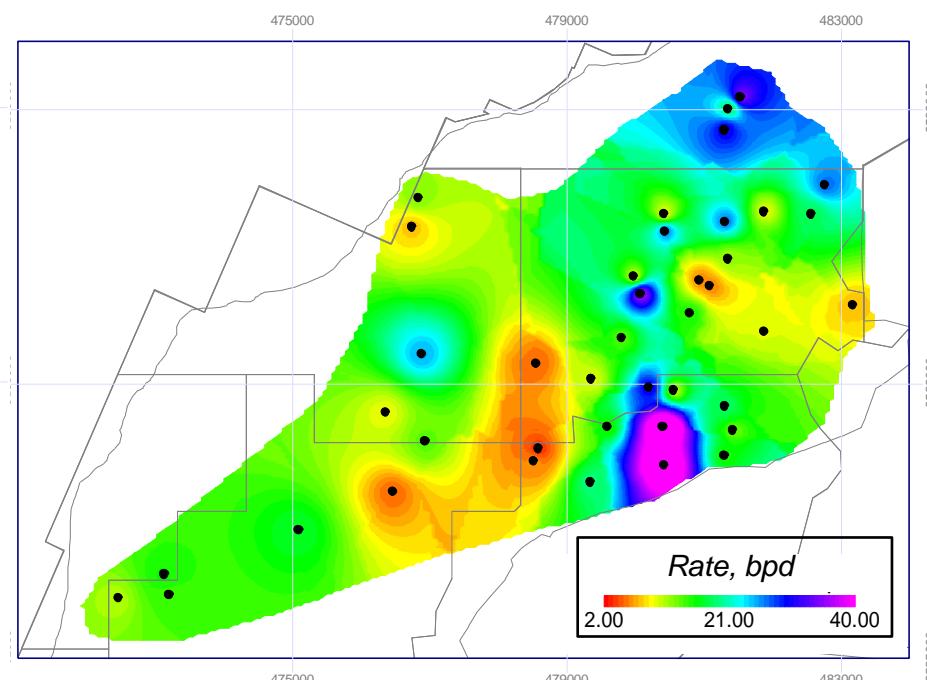


Validation

Forecast Rate



Real Rate



Conclusions

1 CONTEXT

2 OBJECTIVE

3 THEORETICAL BASES

4 ANALYSIS AND RESULTS

5 CONCLUSIONS

✓ 4 relevant
conclusions

Conclusions

1. Historical data of minifrac tests always was used to calibrate the main fracture, however in this work it is showed that are usefull to estimate oil permeabilities in mature fields.
2. Identify the closure pressure is a critical point in the process of interpretation. Results of both methodologies show dispersion when there are problems in reach or identify this event.
3. Using both methodologies (Empirical correlation and Modified Mayerhofer) is possible to get a representative value of permeability and generate models for each reservoir. Those models have a good correlation with flow initial rate.
4. The analysis of MiniFrac data could be applied in other reservoirs with similar characteristics in the NorthWest Peruvian.