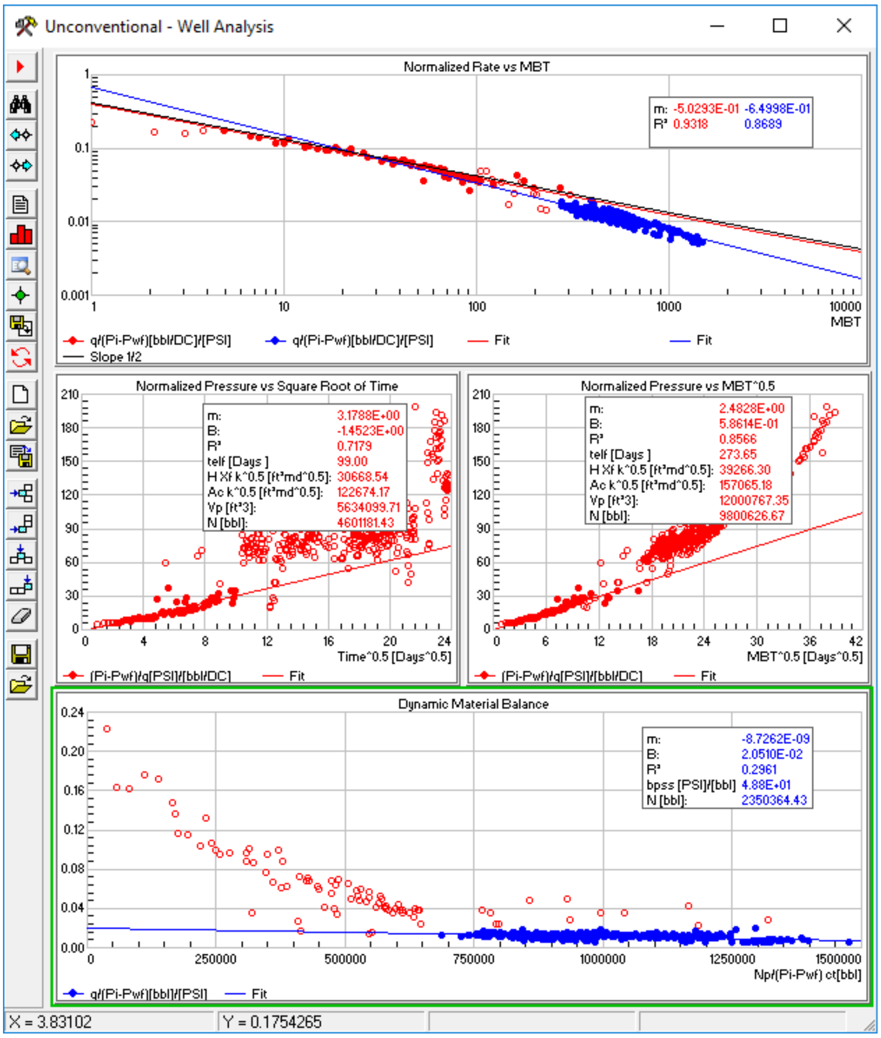
# PRODUCTION DATA ANALYSIS IN SAHARA UNCONVENTIONAL

Sahara Unconventional is a complete suite of tools and methodologies specifically designed to analyze unconventional resources data. It allows making a thorough well by well analysis defining different workflows to standardize the job. In order to do this, there are different production data visualization and diagnostic plots, specialized Rate Transient Analysis and Decline Curve Analysis available for unconventional wells.

This brochure explains how to obtain valuable reservoir information for multi fractured horizontal or vertical wells using visualization and Rate Transient Analysis in Sahara Unconventional.




**The purpose of this workflow is to perform a complete Rate Transient Analysis for unconventional oil or gas wells to obtain valuable reservoir information. This kind of analysis may help to construct a reservoir model to perform analytical or numerical simulation, obtain initial values for history matching or quick production forecasts.**

Unconventional reservoirs differ from conventional ones in that the completion "makes" the reservoir. Since the matrix has very low permeability, an enormous conductive surface area is required between the well completion and the reservoir to attain commercial production rates. Horizontal wells with multiple hydraulic fractures are the most popular technique for exploiting low and ultra low gas and oil reservoirs. The success of the unconventional multi fractured horizontal well depends on the creation of a Stimulated Reservoir Volume (SRV). With this model the reservoir consists of a stimulated reservoir volume surrounded by the unstimulated matrix (Figure 1.a). The SRV consists of a network of fractures and matrix blocks. It describes the connected hydrocarbon pore volume that is accessible by the fracture network.

As described in Figure 1.b the commonly accepted model is an horizontal well consisting of a number of fractures with equal dimensions, equal spacing and identical properties. No flow boundaries are formed between fractures. So, the system is equivalent to a single fracture multiplied by the total number of fractures and only a single fracture needs to be modeled.

The use of this type of completions is expected to create a complex sequence of flow regimes. Different flow regime sequences have been suggested for different geometries. A typical sequence is: first, bilinear flow appears at very early times when two linear flows exists, one within the fracture (towards the well), and one within the formation (towards the fracture); second, linear flow from the formation into the fractures appears. This is the most important flow regime in production analysis. After that it will depend on the system geometry and how much the surrounding system is contributing to the SRV. If matrix permeability is extremely low, boundary dominated flow will come next as the limits of the SRV are reached. Instead, if the matrix is contributing, a more complex sequence of flow regimes will appear.

**The proper identification of the production data points flowing under the different flow regimes is critical to perform a good Rate Transient Analysis.**

How production declines in unconventional wells is shown in Figure 2. Initial production is dominated by the high permeability but low storage fracture system, and therefore declines rapidly. The ultra low permeability matrix provides stable long term production. Unconventional wells often shows transient behavior that can last for several years, and during this transient period they show linear flow. Regular measurements of daily production rates and wellhead or bottom flowing pressures can provide important information about well completion, stimulation and formation parameters. If we combine them with specialized analytical solutions of diffusivity equation we obtain what we usually call Rate Transient Analysis.

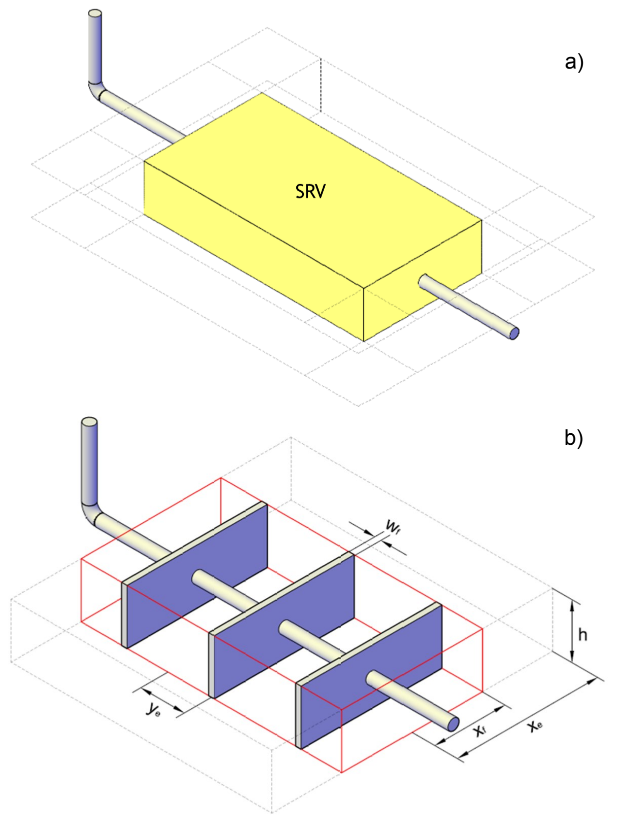


**Figure 1.** a) Scheme of the SRV and surrounding unstimulated matrix. b) Commonly accepted model for the SRV: horizontal well consisting of fractures of equal dimensions, equal spacing and identical properties. $X_f$ is the fracture half length, $y_e$ is the spacing between two adjacent fractures.

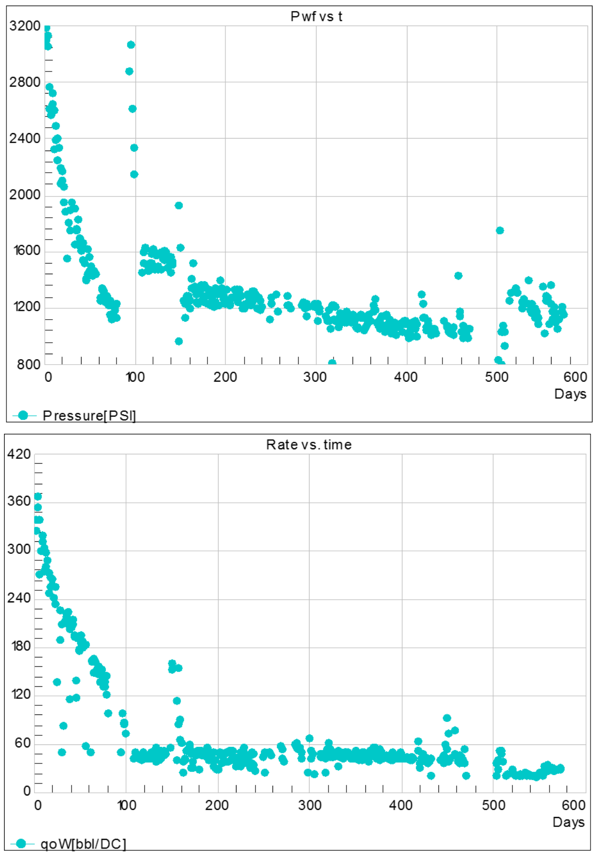


Figure 2. Rates and pressure daily production history for a typical unconventional well.

### Traditional Rate Transient Analysis

A traditional RTA for unconventional resources would include a first step in which we try to identify the different flow regimes through diagnostic plots, and a second step in which we analyze linear flow. Then, if boundary dominated flow is observed we can determinate the connected hydrocarbon pore volume from the Dynamic Material Balance Plot. Figure 3 shows a typical workflow for production data analysis in unconventional wells.

**Workflow for Production Data Analysis**

- Visualization
  - Visualize historical production data behavior
  - Check for correlations between variables
  - Identify and remove anomalous data points
- Flow Regime Identification
  - Log-Log plots
- Linear Flow Characterization
  - Specialized plots (Characterize SRV properties)
- Boundary Dominated Flow Characterization
  - Flowing Material Balance (Estimate SRV)

RTA

**Figure 3**. Typical workflow for production data analysis

**Visualization and pre-processing of the production data is crucial to achieve good results from Rate Transient Analysis. Sahara Unconventional allows obtaining an integrated visualization of the production history and an easy and interactive way to study and eliminate anomalous points.**

### Identification of flow regimes - Diagnostic Plots

The following charts help to identify flow regimes when plotted on a log-log scale:

- q/ (pi – pwf) vs time
- q/ (pi – pwf) vs MBT (Q/q)

Other common Diagnostic Plots (Log—Log):

- Rate vs time
- Rate vs MBT
- Cumulative vs time
- Rate/Cumulative vs time

| Slope | Flow regime |
|---|---|
| 1/2 | Linear |
| 1/4 | Bilinear |
| 1 | Boundary |

**Figure 4**. Expected slopes of the straight lines for different flow regimes in a normalized rate versus time or material balance time plot in log-log scale.

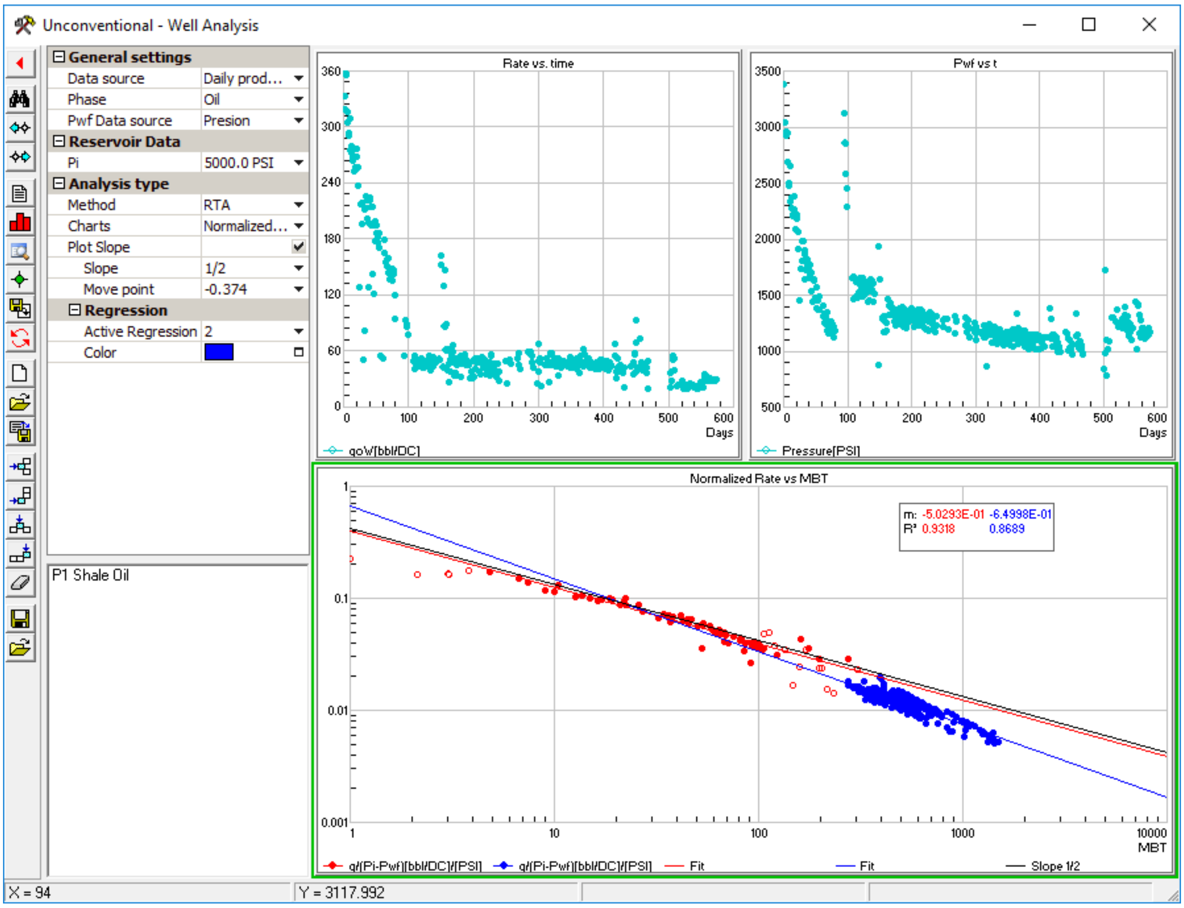



**Figure 5**. Visualization and identification of linear and boundary flow regimes in a Normalized Rate against Material Balance Time plot.

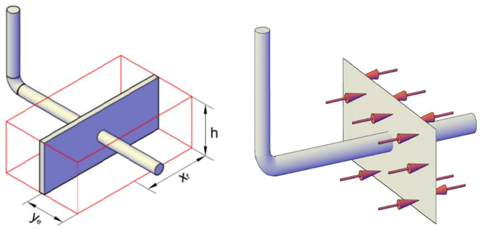
## Linear Flow Analysis - Square Root of Time Plot

This is the specialized plot for linear flow. It may be diagnosed by a half slope on a log-log diagnostic plot or by a straight line on a square root of time or material balance time plot. From the square root of time plot it is possible to obtain the linear flow parameter from the straight line slope. Sahara Unconventional allows obtaining different results by dynamically changing permeability. Combining the slope of the straight line and the time of end of linear flow (Telf) it is possible to obtain an estimation of the drainage area, pore volume and original hydrocarbons in place from linear flow.

## Boundary Dominated Flow Analysis - Dynamic Material Balance

If the system has reached boundary dominated flow, then the Dynamic Material Balance (DMB) plot may be used to estimate connected hydrocarbon pore volume. For unconventional reservoirs the hydrocarbon volume obtained using DMB may be interpreted as the SRV connected to the well.

**All the results obtained from the analysis can be saved and displayed in the Map Window or used for statistical analysis.**




$$\frac{P_i - P_{wf}}{q} = constant\,\frac{B}{A_c\sqrt{k}}\sqrt{\frac{\mu}{\varphi\, c_t}}\,\sqrt{t}$$

$$m = constant\,\frac{B}{h\,x_f\,\sqrt{k}}\sqrt{\frac{\mu}{\varphi\, c_t}}$$

$$y_e = constant\sqrt{\frac{k\,t_{elf}}{\varphi\mu c_t}}$$

a)

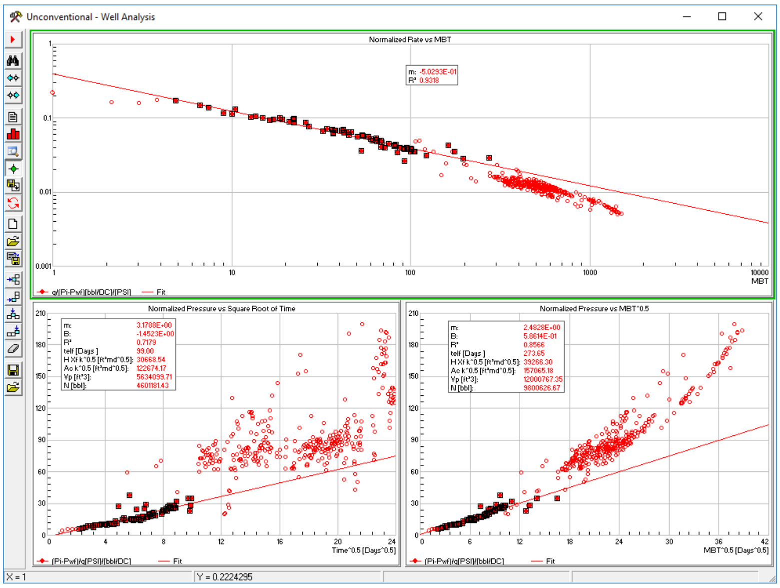



**Figure 6**. a) Model used to characterize linear flow (based on Wattenbarger (1998)). b) Identification and characterization of the linear flow performed in Sahara Unconventional

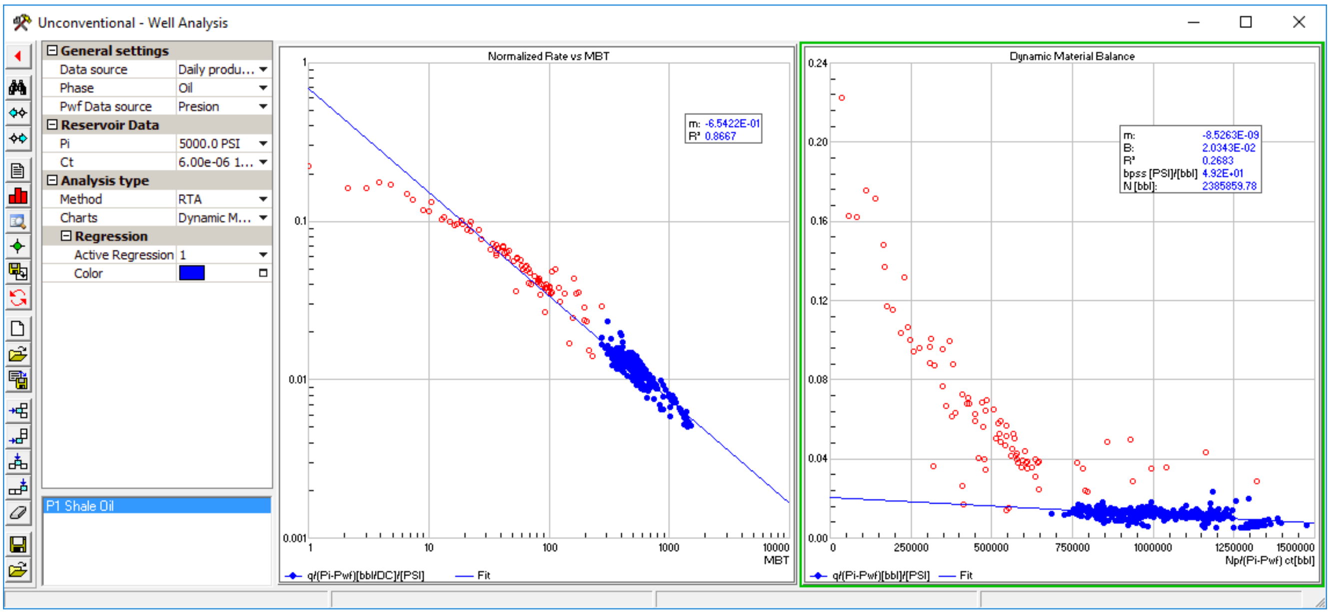



Figure 7. Boundary dominated flow identification in a normalized rate vs MBT plot. Estimation of the hydrocarbons in place using the boundary dominated flow points in the Dynamic Material Balance plot for an oil well.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