Real Time Petrophysical Data Analysis for Well Completions Installed in Oil Fields in the Amazon Basin in Ecuador

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Abstract

Petrophysical interpretation of Logging While Drilling (LWD) data, acquired real time or later downloaded from memory data, is applied to estimate valuable reservoir rock and fluid properties. Permeability is derived from porosity while fluid saturations from resistivity logs. Petrophysical interpretation output depends on log data quality control, local area geo-reservoir-knowledge and understanding of tool physical principles. This is of paramount importance when core data is not available, and then core calibration is absent.

Petrophysical data interpretation results are the most valuable input for updating any base case completion scenarios, for last calibration and refinement of the completion hardware design, prior to its installation in the ground. It is recommended to include several sensitivities and scenarios to assess well completion performance dynamic ranges in terms of fluid rates, water cut and available drawdown pressures. Preparation of cross-plots, standard deviation flags and petrophysical attributes are all integrated to minimize risk and uncertainties related to both reservoir rock and fluid properties.

Both LWD data quality control and petrophysical interpretations are often performed parallel and or simultaneously to ongoing drilling operations. Often, time is short between the drill bit reaches TD to the installation of the completion hardware.

This paper presents the methodology, workflow and only a couple of field examples of successful petrophysical-completion synergism in recent well completions installed with ICDs and AICDs in oil producer wells in Ecuador Amazon Basin.

Introduction

Currently, all drilled wells include Measurements While Drilling (MWD) and Logging While Drilling (LWD) real time log data acquisition independently if a well is drilled for exploration, appraisal, delineation, production or injection. Acquired real time data is a valuable input for a sound petrophysical evaluation of reservoir targets and of paramount importance for designing any completion type solution to produce or inject fluids. Besides log data and its interpretation is a unique source of information of rock and fluid properties for a final calibration of predicted models, base cases as an aid to install an efficient completion hardware.

Depending on the well geometry, wells are completed with a variety of completion equipment, from conventional slotted liners, to standalone screens (SAS) and only recently with ICDs and Autonomous Inflow Control Devices (AICDs) and or Interval Control Valves (ICVs), usually incorporating some level of compartmentalization and zonal isolation with swellable packers.

LWD logs are retrieved either from real time data or from memory data. After data quality control, it is followed by a quick look petrophysical evaluation which often is performed simultaneously with ongoing drilling operations. This process is very fast, because the limited time between the drill bits reaches Total Depth (TD) until installation of the final completion architecture.

Rock properties such as permeability are extracted from inversion of porosity logs while the fluid saturations are from resistivity logs (duly corrected for salinity effects). There is no standard methodology to extract these parameters, therefore quality control, local area knowledge and tool principles are a must. This is particularly important when core data is not available, and then core calibration is absent.

The completion refinement should include and sense several and multiple scenarios to predict well performance dynamic ranges and thus minimizing uncertainties related to both rock and fluid properties.

Geo-Reservoir Challenges

Geologically the Oriente Basin is part of the Upper Amazon River drainage system and covers an area of approximately 80,000 km2 which is very prolific for oil and gas production. It is geologically continuous with the Putumayo basin in Colombia and the Marañon basin in Peru, separated only by geological arches located north and south east of the basin. Figure 1 shows the Bloque 15 location and a generalized stratigraphy with related reservoirs.

The main reservoirs are in clastic rocks, both consolidated and non-consolidated sandstones and exhibiting a wide range of reservoir fluid and rock properties. Fluids API degrees and viscosity often varies areal from 4 cP, 6 cP, 8 cP, 12 cP, 22 cP, 47 cP, 67 cP, 110 cP , 140 cP, and greater than 240 cP.

Initially, the Oriente Basin oil fields were producing from low deviated wells and were completed conventionally (mostly slotted liners), often resulting in a) an uneven reservoir influx, b) without pressure adjustment, c) non-uniform an selective reservoir drainage, d) strong and early water coning, e) well interferences and f) non-optimal area sweep and leaving compartments of by-passed oil. Other wells were completed with dual string solutions to produce from two zones simultaneously but still affected by early coning.

Figure 2 shows a visualization of associated reservoir challenges.

Methodology

A priori, an initial completion case model and scenario is prepared, which is based on proposed well trajectory and well offset geo-reservoir data. Later, during drilling, geo-control and navigation data is integrated. Here, LWD availability and its sound petrophysical evaluation and interpretation is added into the initial base case and refined and calibrated with field all available data measurements. Then, the completion is refined and or totally modified depending on reservoir rock and fluid properties obtained from petrophysical interpretation of LWD data and or wire line logs.

A workflow is developed for a synergetic and cross-fertilized interrogation all available data and operational risk minimization and among the Operator Asset Team and Service company, including:

1. Holistic view and follow up of well prognosis, geo-navigation and landing.
2. Insight of LWD real time logs, anywhere and composite visualizations of GR, Resistivity, Porosity and Neutron logs, together with navigation and prognosis to TD of the well.
3. Preparing a preliminary well completion proposal and mechanical state of the well.
4. Evaluation of completion alternatives, based on parallel pretrophysical evaluation results.
5. Sensing expected fluid rates, available drawdown pressure and cumulative oil completion responses.
6. Refining and calibrating the final completion ready for installation: the completion option that show optimal performance e.g. flux balancing, water cut reductions and area sweep.
7. Well clean-up and post-completion procedures and well delivering to production.

Standard deviation flags should be also estimated along the way, meaning that several scenarios should be performed during the petrophysical evaluation such as for water salinity effects in the output variations of the saturation and permeability ranges, all efforts addressed to minimize potential risk.

A Recent Type of Well Completion Hardware installed in Ecuador

Well completions hardware has evolved from conventional slotted liners to a variety of Inflow Control Devices (ICD), mostly acting passively downhole to Interval Control Valves (ICV) components of intelligent and smart wells which allow for an active reservoir monitoring. Figure 3 show the Autonomous Inflow Control Devices (AICDs) installed to minimize Heel-Toe effects, delay early well coning, balancing flux, adjusting pressure and lowering water cut, along the entire wellbore, thus allowing for well production longevity, an efficient reservoir drainage and area sweep.

Examples: Well completion cases

The AICD completion option was chosen, to restrict the production of water and delay and early breakthrough to minimize water cut.

Figures 4 shows permeability and fluid saturation profiles interpreted from LWD data, used to refine the final AICD completion (Well 1).

Figure 5 shows the integration from petrophysical interpretation results through flux responses of the final AICD completion (Well 2).

Summary

The petrophysical-completion integrated methodology and workflow is successfully applied in Ecuador oil wells and this type of analysis and approaches has been extended to other completions types or completion solutions in the area.

References

Davila, E., Almeida, R., Vela, I., Pazos, J., Coello, K., Chinellato, F., Humbert, O. and Porturas, F. [2009] First Applications of Inflow Control Devices (ICD) in Open Hole Horizontal Wells in Block 15, Ecuador, SPE123008, LACPEC, Cartagena, Colombia, 31 May-3 June.

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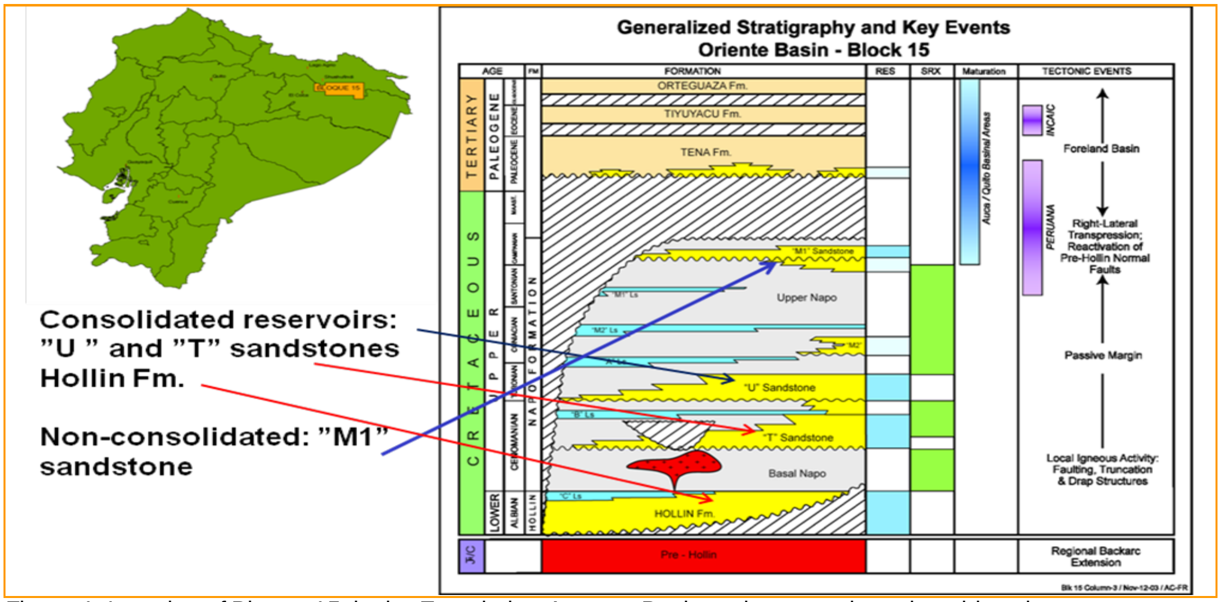

Figure 1: Location of Bloque 15, in the Ecuadorian Amazon Basin and a general stratigraphic column.
Main reservoirs comprise consolidated sandstones e.g. U, T, and Hollin Fms. and non-consolidated sandstones e.g. M1 Fm.

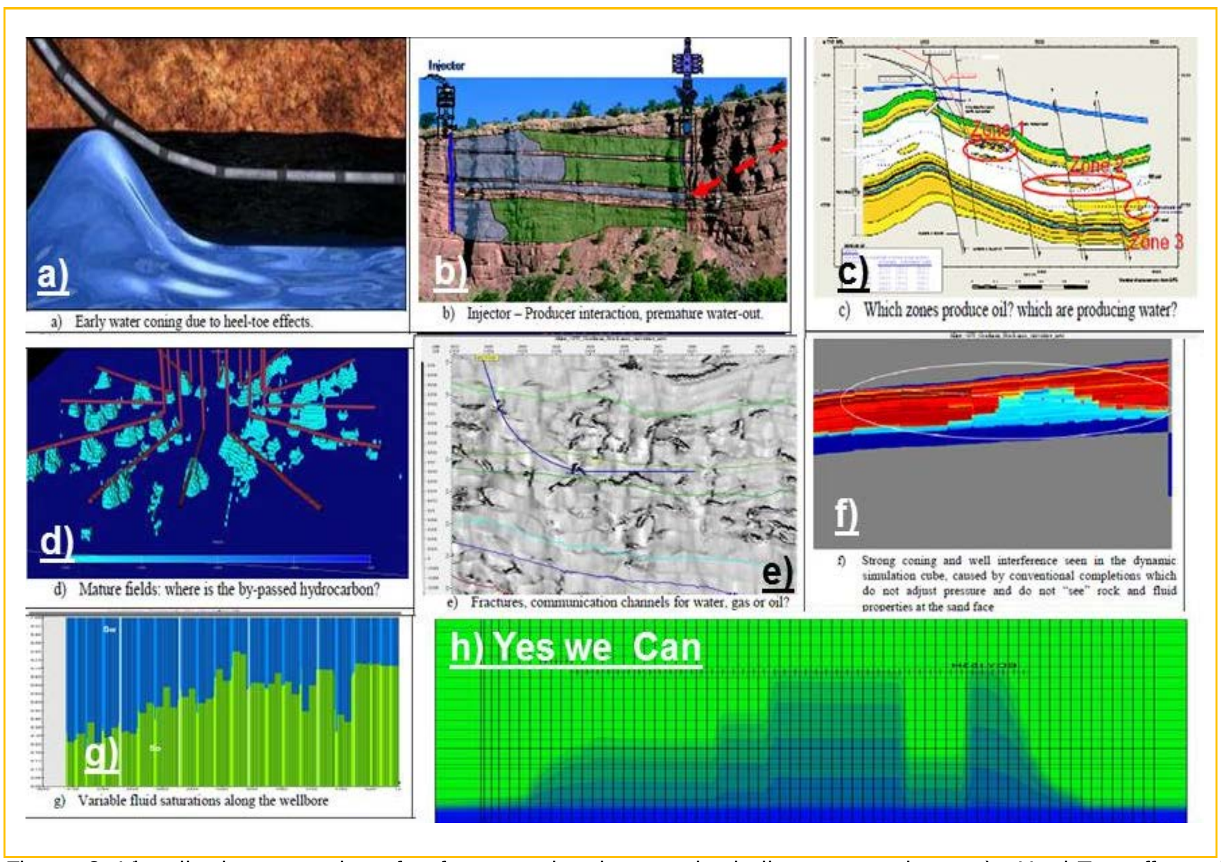

Figure 2: Visualization examples of a few associated reservoir challenges anywhere: a) Heel-Toe effects, b) Viscous fingering, c) Lateral and vertical reservoir continuity, d) Non-uniform and irregular reservoir drainage (where are located zones with economic residual hydrocarbon saturations?), e) Natural fracturing and which is the type of fluid in the fracture system and its lateral and vertical connectivity, f) Strong water coning and by-passed oil, where are remaining mobile residual oil saturations, g) Mature fields, saturation profile, h) Scenario of differential strong coning and active aquifers. Besides, in the Ecuadorian Amazon Basin it is found hydrocarbons with a wide range of fluid densities and viscosities e.g. varying from light to more than 240 cP fluid viscosities, and to very heavy oil, often with variable PVT regions and very high mobility contrasts resulting in very high water production rates and associated surface treatment costs.

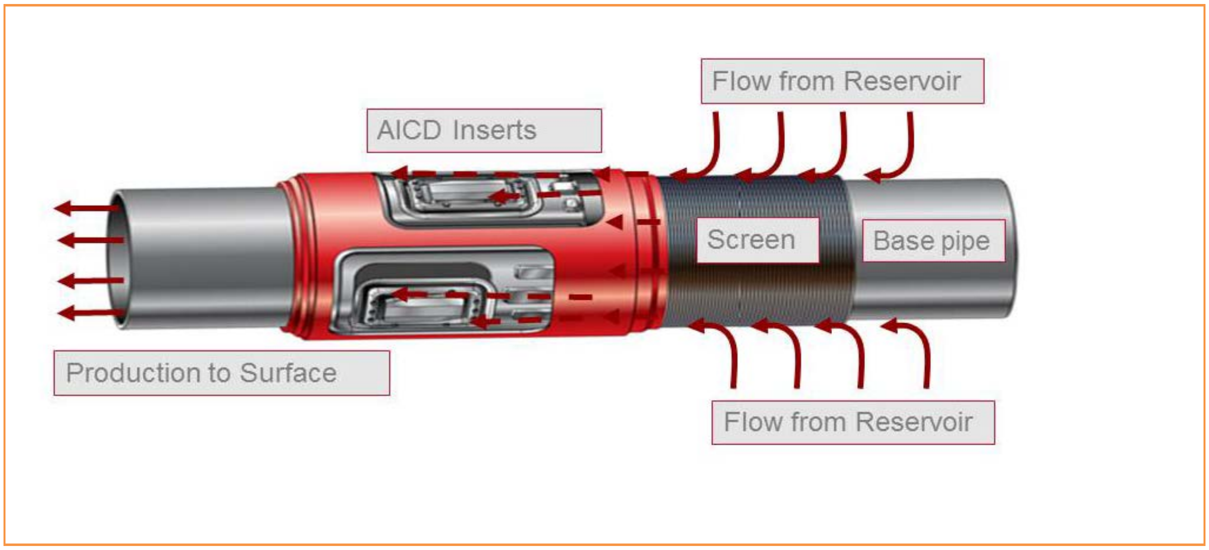

Figure 3: Example of an Autonomous Inflow Control Device (AICD) completion hardware which is custom made, fit-for-purpose and having two main components, one) the screen part for solids and erosive particles control function and two) AICD housing equipped with high metallurgy inserts. The fluid from the reservoir enters the screen (shown by the arrows) and then flows between the screen and the base pipe into the inserts where a viscosity selector, flow switch and a flow restrictor are acting simultaneously to preferable direct oil into the production string thus restricting and minimizing entrance high mobile fluids such as water and or gas. The selection of the number of inserts depends on available drawdown pressure, target rates and production strategy. An AICD completion hardware selection benefits of the integration of well geo-control, geo-steering, landing and petrophysical interpretation of LWD data, highly recommended to be performed while drilling.

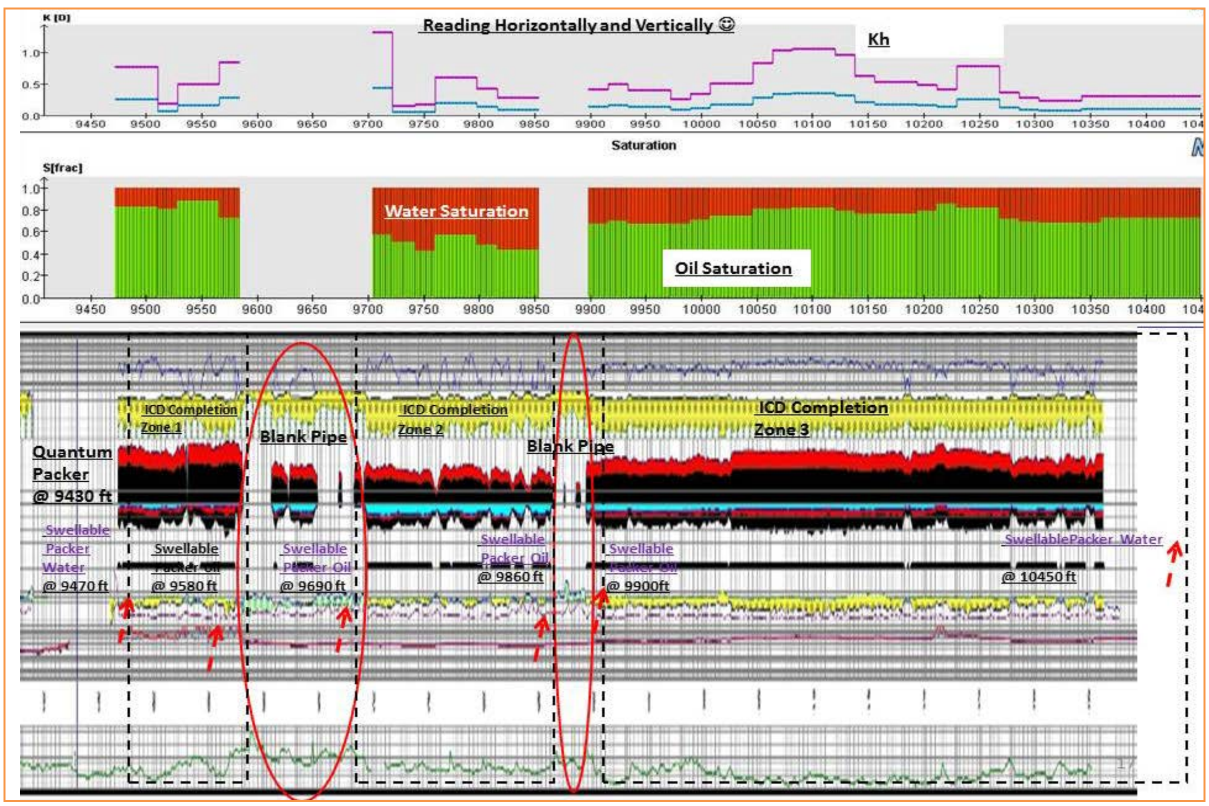

Figure 4: Petrophysical interpretation along the wellbore. Here, permeability and fluid saturations are up scaled to the completion hardware length to refine the final AICD completion design, for wellbore zonation, to by-pass non-pay intervals and place zonal isolation to avoid fines migration.

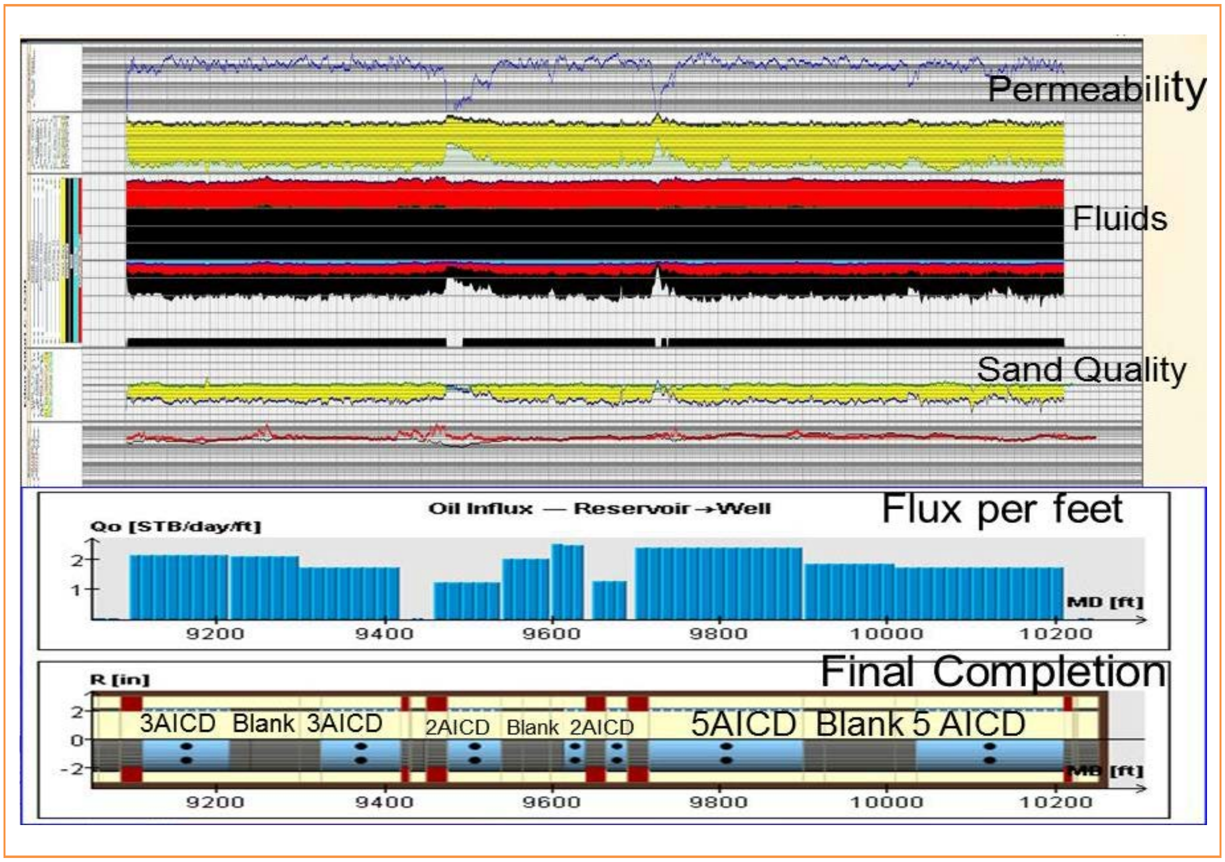

Figure 5: Composite section of some steps followed to install a successful AICD completion. a) on top, petrophysical evaluation of LWD logs, very useful for formation zonation based on correlations between GR, Resistivity, and Neutron-Density logs, include the permeability and saturation profiles valuable input to evaluate the production potential of the AICD completion, b) centre, flux equalization response of the completion, and c) completion hardware components distribution along the wellbore.

Last opportunity to refine the well completion and to interrogate and evaluate available data vertically and horizontally.