UNCONVENTIONAL PRODUCTION ASSESSMENT (UCR PAW)

Maximiliano Giraldo[1]

1: Chevron. mgkp@chevron.com

Keywords: UCR, Type Curve, Exploration

RESUMEN

Saber cuánto hidrocarburo producirá un pozo no convencional es clave para evaluar la exploración y nuevas adquisiciones al saber cuántos recursos hay en un play, bloque o concesión, para finalmente correr los económicos de la oportunidad y definir las métricas de valor para tomar decisiones informadas. Este documento describe el flujo de trabajo desde un enfoque de ingeniería petrolera con la integración de la evaluación de geología y geofísica para brindar una evaluación sólida del potencial de producción no convencional. El flujo de trabajo muestra un enfoque paso a paso basado en lo siguiente: selección de superficie con información geológica y geofísica en sitio, incluidos registros de pozos, sísmica, diseño de pozos, informes de operaciones, etc. en segundo lugar, una evaluación petrofísica de la formación de interés seguida de un modelado de cuenca para estimar la madurez de los hidrocarburos respetando muestras de fluidos, datos PVT y relación gas/petróleo, analizar el rendimiento del pozo junto con el diseño de terminación, realizar análisis curvas de declino (DCA) y análisis de transiente de caudales (RTA) solo si hay suficiente información disponible. Llegado a un nivel máximo de evaluación, una simulación de yacimiento (torta de capas simplificada con modelo de fracturas planares) acoplado con un diseño del experimento mostrará parámetros clave de incertidumbre que afectan la productividad. Finalmente, la comparación del método anterior con el análogo geológico seleccionado concluirá la evaluación del potencial de producción, que luego se representará mediante la curva tipo (TC). Una vez que se completa el ciclo, se puede iniciar uno nuevo cuando se disponga de nueva información sobre el pozo, sísmica, etc.
Usando este flujo de trabajo, se puede llevar a cabo una evaluación precisa, metódica y consistente de la productividad de un nuevo campo no convencional, donde se integra la información geológica, geofísica y de ingeniería de petróleos.

INTRODUCTION

The main purpose of this paper is to present an Unconventional Production Assessment Workflow (UCR PAW), that helps Petroleum Engineers to collect information, evaluate information, compare, and combine geological aspects with engineering ones that allow methodical and comparable evaluations over time and give the engineer a logical line of thought so that the evaluation of the opportunity is less subjective, and combines all subsurface disciplines.

UCR PAW promotes interdisciplinary work and helps the convergence of criteria in the evaluation of the productive potential of shale by integrating the fundamental principles of rock, hydraulic fracture, stimulated reservoir volume and the flow between these and the well to the surface. The workflow has been already used to evaluate several Vaca Muerta opportunities, as well as new frontier shale opportunities around the world.

THE ROLE OF UCR ASSESSMENT AND EXPLORATION

The role of UCR resources assessment focus on replacing produced barrels, but it also emphasizes that the unconventional barrels that are being searched must be produced at an appropriate profit threshold. As such, there is much more focus now on delivering reserves, knowing what could impact converting resources to reserves early in the exploration process. See schematic on Figure 1, The role of UCR assessment and exploration.

Therefore, companies focus the effort to assess productivity early, usually known as "well type curve" to estimate the following:

- UCR Resources and reserves on a given block/area.
- EUR: Estimate Ultimate Recovery per well.
- Run economics.
- Develop asset plans.
- Diversify portfolio
- Evaluate exploration and acquisitions and rank future drilling activities
- Business plans production forecasts and future market estimations

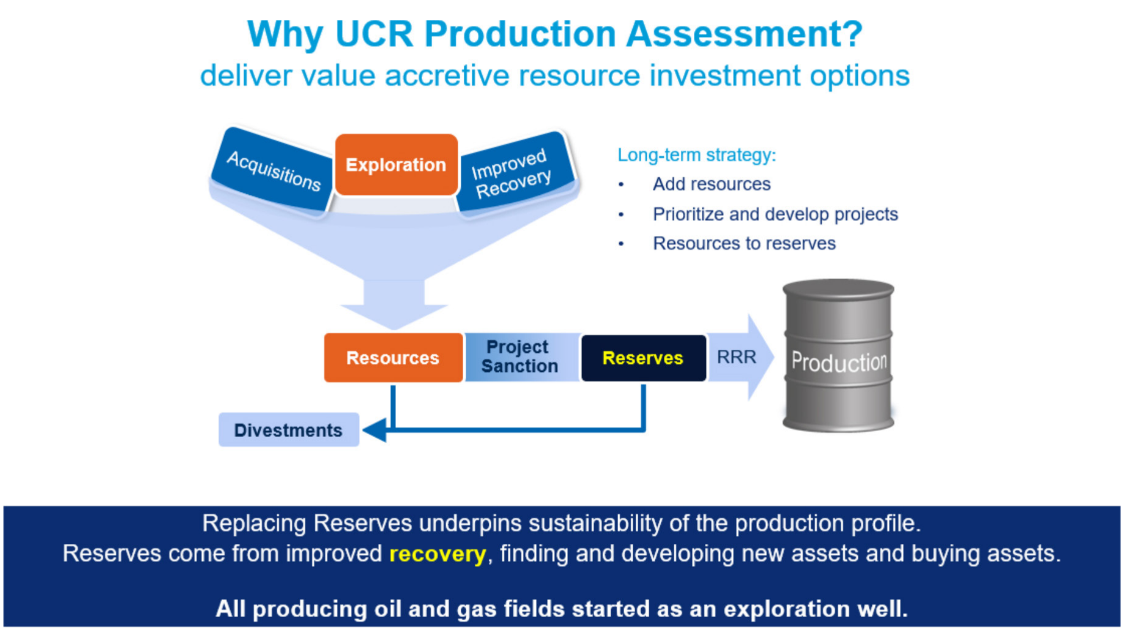

Figure 1. The role of UCR assessment and exploration.

Finally, the main goal is to maximize returns by making informed decisions using productivity information which often is very limited for new opportunities, given the lack of wells with information. The common way to measure an unconventional production potential is a Type Curve.

UNCONVENTIONAL PRODUCTION ASSESSMENT WORKFLOW (UCR PAW)

To assess the unconventional shale productivity, a 9 steps workflow is proposed (Figure 2, Unconventional Production Assessment Workflow (UCR PAW)). The starting point is the search for wells information, meaning wells drilled and completed and/or put on production on the targeted shale. Wells information that is being searched are: well logs, directional surveys, well tests, stimulation design, perforations, static and dynamic pressure, choke management, artificial lift system, PVT, water lab samples, PLT logs, oil, gas, water and sand production rate, seismic and microseismic, maps, stress logs and basin stress information, core, core plugs and cutting information, mud logs, etc. Information should be quality checked and quality assured. Data should be reliable and consistent or otherwise discarded.

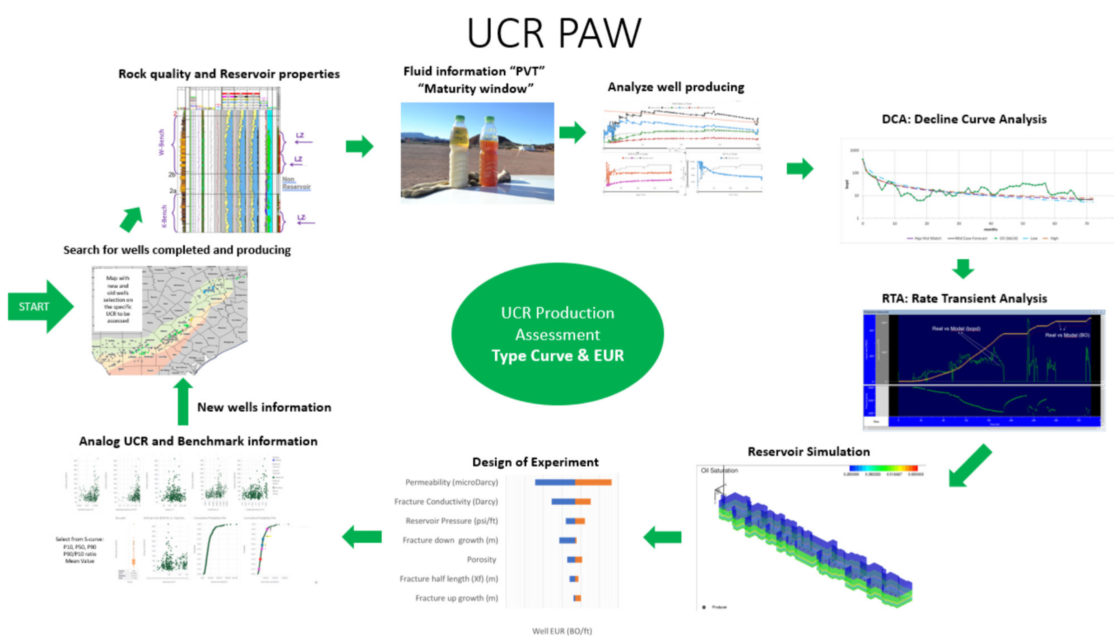

Figure 2. Unconventional Production Assessment Workflow (UCR PAW).

The second step is to analyze wells geology, geomechanics and petrophysics, assess mineralogy, depositional environment, TOC, porosity (type of porosity), movable fluids, stress regime (identify fracture barriers). Merge all this information together to define potential in different benches. It is recommended that benches should be defined within 30 to 40 meters thickness range, although the navigation interval should be at maximum of +/- 5 meter of the landing point. Benches are defined by setting cut off to the petrophysical and geomechanically rock properties. Typically, net cut offs are, clay volume, TOC, porosity, hydrocarbon saturation and stress contrasts (usually searching for a different rock deposit acting as a barrier). On the geomechanically side it is needed to address the rock stress regime, normal, strike slip or reverse. If geomechanics are well known, a robust drilling and completions designs could be achieved to maximize well production.

Defining the number of possible benches is very important because it will define development scenarios and well placement in the 3 dimensions and total resources per unit of area which is usually done on the logic of wine rack design. An example is shown on Figure 3, RQ type log

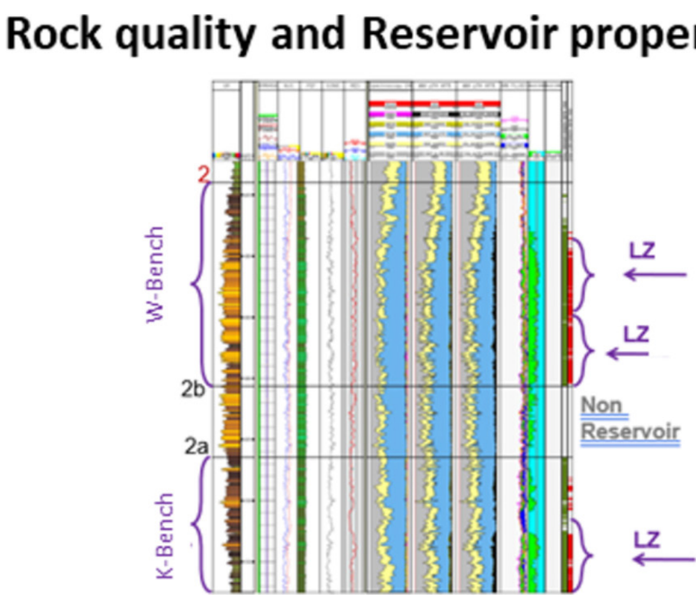

Figure 3. RQ type log.

The following step (3rd) is to address the rock maturity. Petroleum Engineers should evaluate and validate PVT report, oil samples and gas chromatography, as well as the GOR trend during the time wells were tested or were on production. During this process it is extremely important that fluid samples match the basin modeling results explaining which is the fluid type that could be found inside the rock over the area of interest. Some of the questions that need to be answered are, how fluid maturity changes from one well to another, how does basin modeling address maturity changes across the entire acreage and how much hydrocarbon remains in place? Total resources density on the defined area of interest, that should be ballpark when compared to the selected analog resource density as well as the final estimate type wells and number of benches.

As a summary the key parameters to be addressed are:

"Maturity window": The types of unconventional hydrocarbon are controlled by the evolution of the source rocks. Unconventional hydrocarbon resources (oil or gas content) are affected by the temperature and pressure fields, and their preservation which is crucial (burial history).

Fluid information, Pressure, Volume and Temperature (PVT) report are very important pieces since can clearly describe which type of hydrocarbon is accumulated in the shale rock. Commonly the sweet spot is focused on the following maturity windows: volatile oil, gas condensate and dry gas. Although, on some special cases black oil could have high productivity.

Impurities are very important since they can impact realization price for both oil and gas. Moreover, impurities can have a huge impact on the cost of the facilities, impurities are usually:

Gas: N_2, CO_2, O_2 and H_2S

Oil: sulfur, sometimes dissolved H_2S, paraffins and asphaltenes.

Now is time to analyze well production, this fourth step seems to be simple, but it takes the most of a petroleum engineer skills and experience since most of the analysis is qualitative. For example, how is the well completion (total sand, proppant, perforations, etc.), how long was the flow test, how was the well clean up, water cut, salinity and GOR evolution, how was the choke changed and drawdown rate during the testing and production period, how was test operation overall, etc. Most of these factors do not have a perfect and accurate quantitative relationship with well test production, but they are related and should be assess by the engineers.

On step number 5, engineers will dive into decline curve analysis (DCA). Only wells with enough time and reliable well testing data could be process using this methodology. Obviously, hyperbolic modified method proposed, main variables to be calculated by fitting the equation to the real production trend are initial decline rate (ai), peak rate (qi), hyperbolic factor (b) in other to have a reliable fit for the hyperbolic trend, it is suggested to have at least 18 months on production, else b factor should be caped based on values used on the analog information. The second portion of the DCA modified Arp method is the exponential forecast. Usually on a new shale play, there is not enough production time to reveal this minimum exponential decline rate (Dmin) at which hyperbolic shift to exponential decline, so the Dmin value should be the same as used in the analog shale play, Finally, defining a minimum rate that well reaches economic limit (also known as well terminal rate) is needed. The economic limit could be calculated based on estimated well CAPEX and OPEX. DCA is very important, since this method is used for reserves booking purposes.

Once DCA is done, it is suggested to run DCA fit sensitivities within a range, thus accounting for a low, mid and high estimates.

The sixth step is building RTA model. It could be done only if there is pressure and production information from the wells that have been completed and tested. The methodology is based on setting up a model and history match it. To set up the RTA model, PVT as well as completion and geological data is needed. Another important parameter is the original reservoir pressure which is one of the variables that should be inputted at the beginning and will be calculated on iterations while model is history matched. A recommended best practice is to perform blind tests with the model, to check that model prediction is reliable before running forecasts. The final product will be the well forecast.

Part of the state-of-the-art RTA modeling is running sensitivities on the well design (increasing lateral length, increasing number of stages). Completion sensitivities will set the expectations for new completions technologies (increasing stimulated rock volume (SRV)) versus well performance. Moreover, RTA has several diagnostic plots that could be done to estimate SRV parameters. Finally, it is important to mention that difficulty and data input for RTA analysis is much more than a regular DCA, thus usually engineers use DCA technique as a default forecasting methodology.

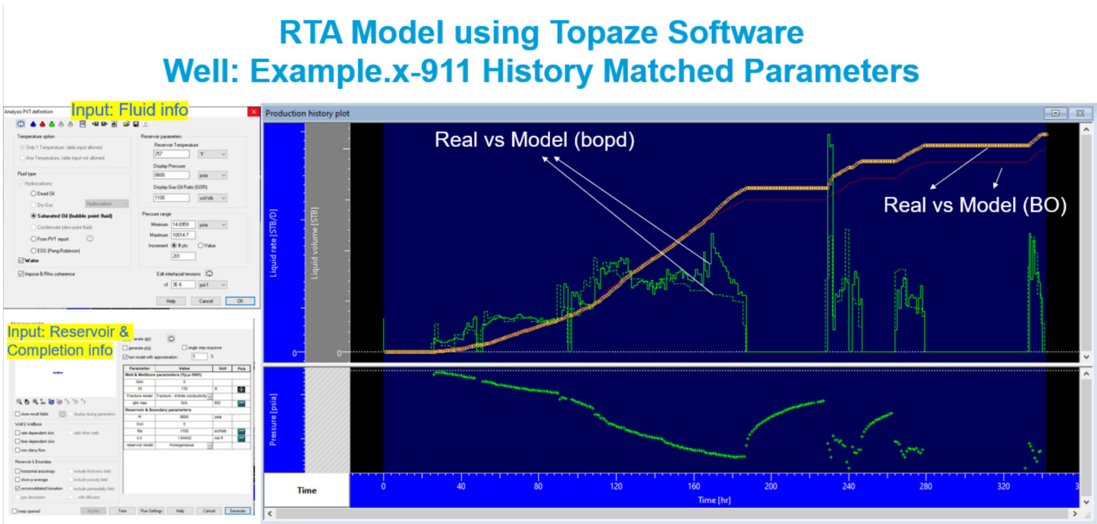

Figure 4. RTA history matched model.

After tackling RTA, it is time to orchestrate a reservoir simulation model, 8th step. Reservoir simulation is thirstier for detailed petrophysical, geological and engineering data than RTA model. Summary of data needed are oil, water and gas rates, detailed petrophysics, rock compaction curves, PVT, lower well completion, upper well completion, drawdown management, etc. History matching the model is important, else simulation forecasting could be non-accurate. Since building a reservoir simulation model is a complex process compared to DCA or RTA as shown on Figure 7, final UCR PAW workflow will deliver a Type Curve.

In order to simplify the reservoir simulation model, it is suggested to use a regular PVT model, set up a layer cake model (with simulation cells of 3 meters thickness (z direction) and dimension of cells on x and y of 30 meters) with planar fractures based on completion clusters and fracture length calculated on previous RTA step (diagnostic plot of Productivity index vs square root of time) and use reasonable multipliers to history match the simplified model.

Once reservoir simulation delivers a reliable well forecast a Design of Experiments (DoE) could be done on step 9.

DoE is a statistical technique that allows analysts to identify and quantify the causes of an effect within an experimental study. In an experimental design, one or more variables are linked to causes or outcomes. In its simplest form, an experiment aims at predicting the outcome by introducing a change of the variables, also referred to as "input variables".

The model variables (inputs) were listed to identify which ones have the highest impact on well performance. For each variable, a most likely value was estimated, which was used to build the simulation model (base case). Afterwards, high, and low cases were estimated. Usually, the normalized well EUR (bo/ft or Mscf/ft) is selected as the Value Measure for well performance and will be compared on each calculation later to assess how variables impact productivity.

To evaluate the impact of each variable, a tornado plot is used. (Figure 3, Design of Experiment).

It is clear on the tornado plot that the top variables have the highest impact on productivity (bo/ft), thus the focus should be set on those top 3 or 4 variables in order to select the location, bench, landing zone, completion design of wells to be drilled.

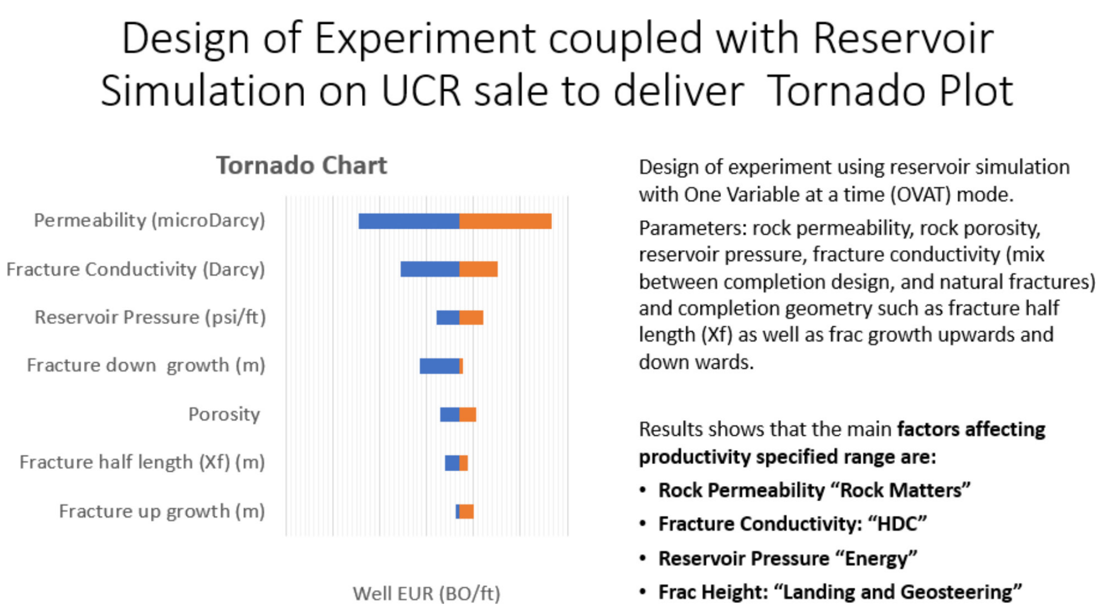

Figure 5. Design of Experiment.

Finally, on step number 10, a geological UCR analog is selected to benchmark production. The selection is based on geology, thus UCR PAW is done within a teaming environment from all subsurface disciplines: geology, geophysics, and petroleum engineering. Analog key parameters to be considered are: Depositional setting, mineral composition, fluid maturity window and GOR, TOC, porosity, clay content, reservoir pressure, reservoir depth and completion. Other cut offs that could be used if there is reliable information such as hydrocarbon saturation. The way to benchmark will be using filters (cut offs) on the mentioned parameters and plot an S-curve for normalized EUR (bo/ft) or (Mscf/ft) (Figure 3, Analog Benchmark). From the S-curve, the P10 (minimum), P50 (medium) and P90 (maximum) are identify and compared with DCA, RTA and Simulation values. One important value obtained from the S-Curve is P90/P10 ratio that should be considered as part of the uncertainty of the expected outcome. This P90/P10 ration is a proxy to a Maximum/minimum ratio that could be increased at the final step to incorporate extra uncertainty range from a new shale play. It is very important to set the P90/P10 range much higher than the analog P90/P10 ratio, there are several suggestions on literature how to assess this ratio. Though, teaming between geologist and engineers should lead to the best P90/P10 ratio to capture the uncertainty range of the UCR under evaluation.

After the full UCR PAW is achieved a productivity potential per foot is selected as a medium case based on all the previous assessment to honor geophysics, geology and reservoir engineering including well completion design. Productivity per foot will be used to develop a Type Curve (TC) that will represent the expected value outcome of a new UCR well.

As mentioned previously, the hydrocarbon production TC is representative of production profile of a well for a specific play, area and/or bench. That is, if you were going to drill a successful well in an area, TC would be the "best representation" of the expected production forecast. The

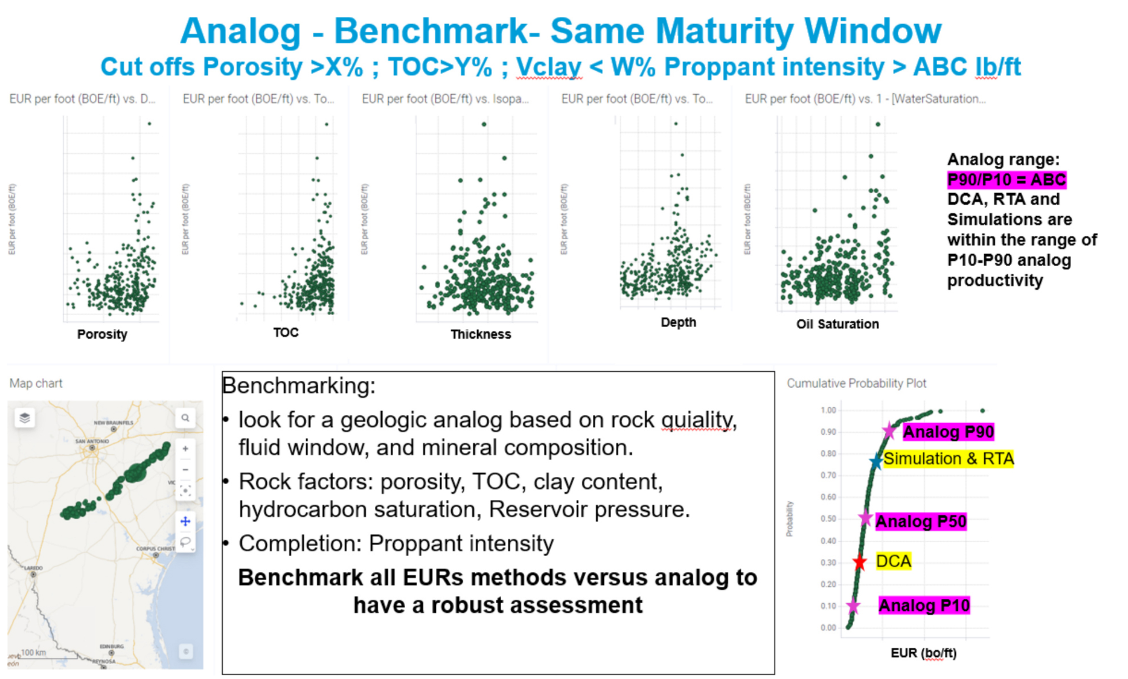

Figure 6. Analog Benchmark.

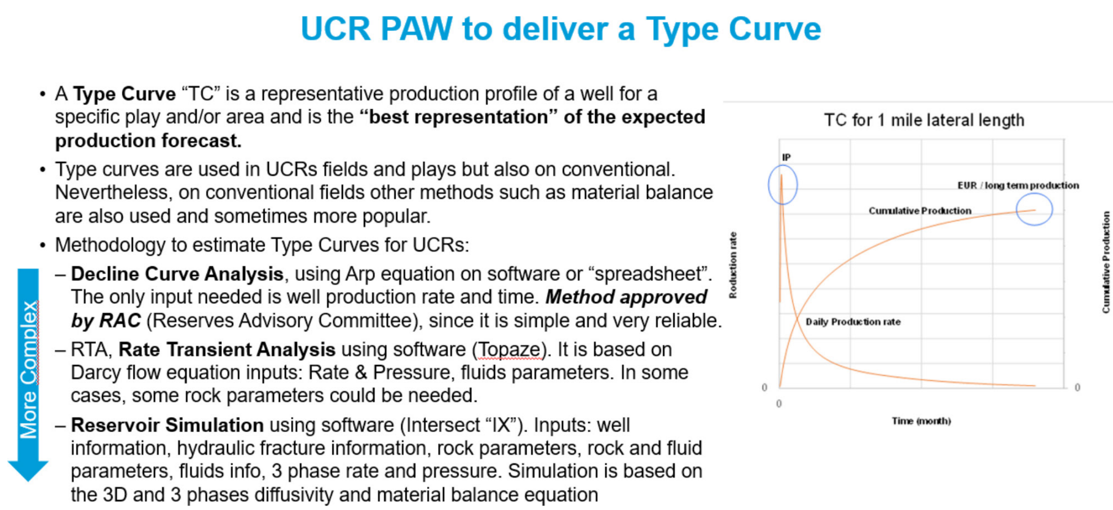

Figure 7. Final UCR PAW workflow will deliver a Type Curve.

total cumulative production from a TC is called, EUR that is the Estimate Ultimate Recovery. As mentioned previously EUR divided by effective lateral length is the suggested way to compare well performance for similar completion design. Oil (BO/ft) & Gas (Mscf/ft or BOE/ft).

CONCLUSIONS

UCR PAW is suggested to be used for exploration of new UCR (shale) potential as wells as assessing new venture opportunities and/or appraisal programs. The proposed is an integrated subsurface workflow to be used including not only petroleum engineering but also integrating geology, basin modeling, petrophysics and geophysics into the assessment. The final UCR PAW product is to develop a TC that shows the expected production potential of a new UCR opportunity.

Main takeaways are:

- Validate fluid information (Oil, Gas Condensate or Dry Gas) and impurities.
- Match Rock Quality and Petrophysical properties with productivity
- Validate Basin model for maturity and overburden history
- Validate Analog production.
- Evaluate key variables affecting productivity.
- Assess Unconventional productivity using 4 methods: Analog, DCA, RTA and Simulation.
- Develop Type Curve matching the completion design
- Calculate EUR for selected wells based on lateral length and completion design
- Estimate total unconventional resources potential based on a minimal, medium, and maximum potential

REFERENCES

S. Amin Gherabatti, Ursula Hammes, Frank Male, Kalle M. Smye and John Browning. 2018, Bureao of Economic Geology, University of Texas at Austin. Assessment of Hydrocarbon in Place and Recovery Factors in the Eagle Ford Shale Play, SPE-189992-PA.

Magaly Alonzo, 2016 Fm. AGRIO (Mb. PILMATUÉ) Ventanas de generación de hidrocarburos y maduración de materia orgánica en la provincia de Neuquén. Ministerio de Energía servicios públicos y recursos naturales, Gobierno de la Provincia de Neuquén.

Miguel Jimenez, Cesar Rojas, Ecopetrol; Yahir Valderrama, Ecopetrol. 2015, Unconventional Resources Technology Conference (URTeC) DOI 10.15530/urtec-2015-2153136. Initial Analysis of Hidrocarbon Potential in the Tablazo Formation; Center and Northern Areas of Middle Magdalena Valley, -MMV- Colombia

Jed Bailey and Lisa Viscidi, The Dialogue, Leadership for the Americas, http://www.thedialog.org, 2016, SHALE DEVELOPMENT AND THE ENVIRONMENT; Policy Lessons for Latin America.

B. R. Meyer, Meyer & Ass. 1989, Three-Dimensional Hydraulic Fracturing Simulation on Personal Computers: Theory and Comparison Studies SPE 19329.

Shing-Ming Chen, 2003, A Generalized Hyperbolic Decline Equation with Rate-Time Dependent Function, SPE-80909-MS.