Unlocking Reserves from a Secondary Reservoir in a Mature Field Through Integration and Engineering Approach: A Case Study from Oriente Basin, M-2 Reservoir, Eden-Yuturi Oilfield, Ecuador*

Nestor Vasconez[1], Luciano Bravo[2], Ricardo Grijalva[2], Raul Jose Baez[2], Anne Valdez[3], Esteban Alba[3], Diego Tapia[3], Jonny Lomas[3], and Martha Castillo[3]

Search and Discovery Article #10978 (2017)**
Posted August 7, 2017

*Adapted from oral presentation given at AAPG Latin America Region, Optimizing Geoscience and Engineering to Explore and Produce in a Low-Price Environment, Bogota, Colombia, May 17-18, 2017

[1]Schlumberger, Quito, Ecuador (NNoguera@slb.com)
[2]Schlumberger, Quito, Ecuador
[3]Petroamazonas EP, Quito, Ecuador

Abstract

This presentation will offer an analysis of the results of several different completion techniques applied to a secondary reservoir in a mature field. These analyses allowed for the selection of the most effective solution for the development of what had been considered a secondary reservoir, optimizing the oil potential of the reservoir and its associated reserves by providing a reduction in workover time and incremental production through the use of an integrated engineering approach. The re-evaluation of the oil potential of this secondary laminated reservoir and its proper development was achieved through selecting the right technology after 15 hydraulic fractures, 13 perforations with propellant, and 8 high density shot perforations. The input data includes the integration of a detailed geological description, petrophysical evaluation, and a reservoir characterization added to pre and post evaluations of the completion techniques supported by production results. Comparing the results as a function of the completion design and its reservoir characteristics helped to determine the right completion scheme for the reservoir in terms of productivity and economics. The integration of the inputs and outcomes of each completion system showed that hydraulic fracturing is the most suitable method to unlock the oil potential and reserves of M-2 reservoir due to the higher productivity it creates and the sustained oil rates seen over time. The technique showed up to a 100% increase in oil production with unaltered water cut levels, which indicates that the fracture has contacted and connected multiple laminated oil-bearing sands. The suggested technique is supported by an optimal correlation between reservoir characteristics, oil productivity, and constitutive laws. The fracturing process was continuously optimized until reaching the planned objectives for the reservoir. The new oil potential, added to the lower water cut of the reservoir, also helped to reduce bottlenecks at surface facilities, which are currently at limit conditions due to high water production from the main reservoirs. Finally, the optimization process resulted in savings at OPEX and CAPEX levels.

References Cited

Baby, P., M. Rivadeneira, and S. Barragan (eds.), 2014, Geología de la Cuenca Oriente: Con el auspicio de SIPEC Ecuador y PETROBRAS Ecuador, 295 p.

Haq, B.U., L. Hardenbol, and P.R. Vail, 1987, Chronology of Sea Levels Since the Triassic: Science, v. 235, p. 1156-1167.

Unlocking Reserves from a Secondary Reservoir in a Mature Field Through Integration and Engineering Approach: A Case Study From Oriente Basin, M-2 Reservoir: Eden-Yuturi Oilfield, Ecuador.

Nestor Vasconez, Luciano Bravo, Ricardo Grijalva, Raul Jose Baez (†), Schlumberger - Kamana
Anne Valdez, Esteban Alba, Diego Tapia, Jonny Lomas, Martha Castillo, Petroamazonas

Agenda

Field overview

M-2 reservoir description

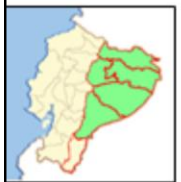
Development & optimization

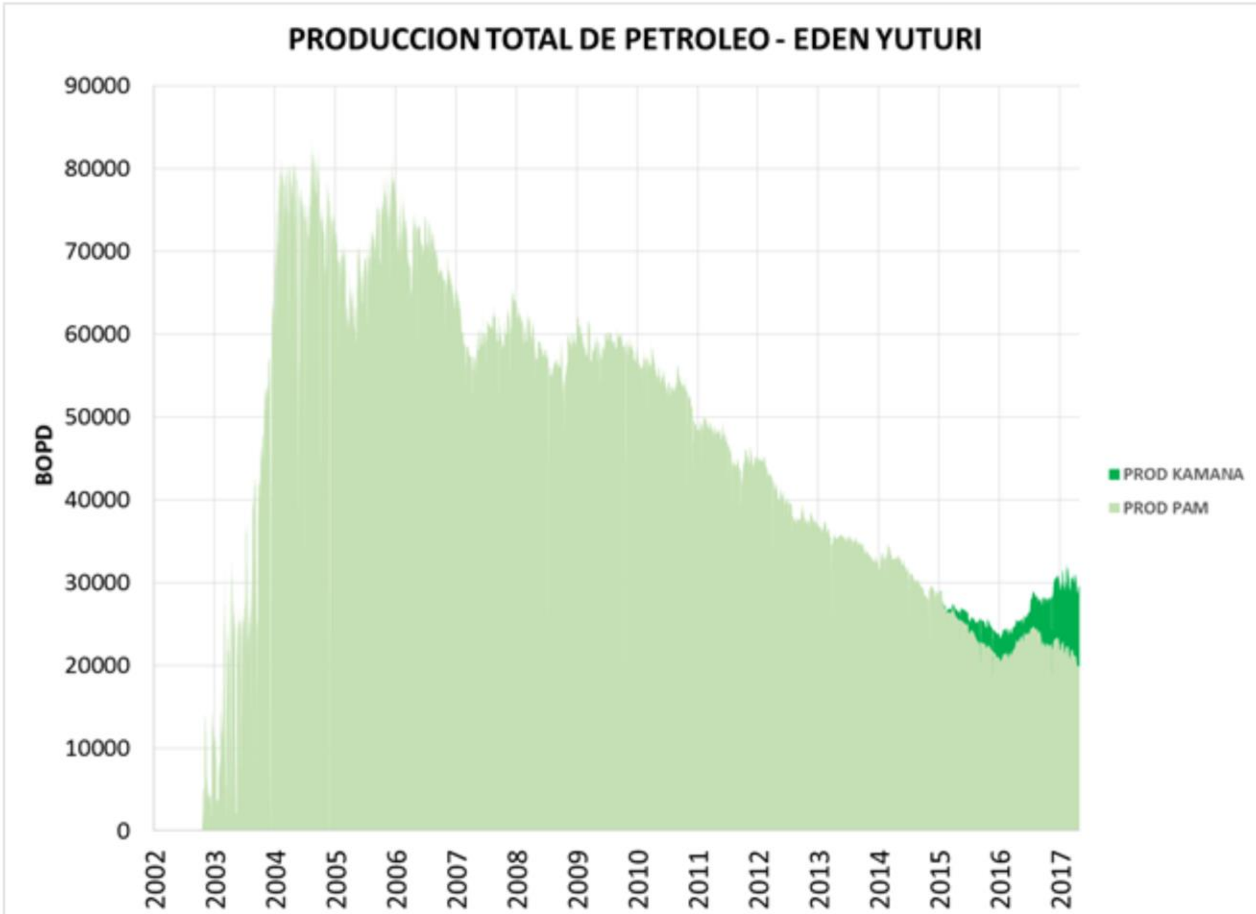
Results & Value

Field overview

PETROAMAZONAS

Kamana Services





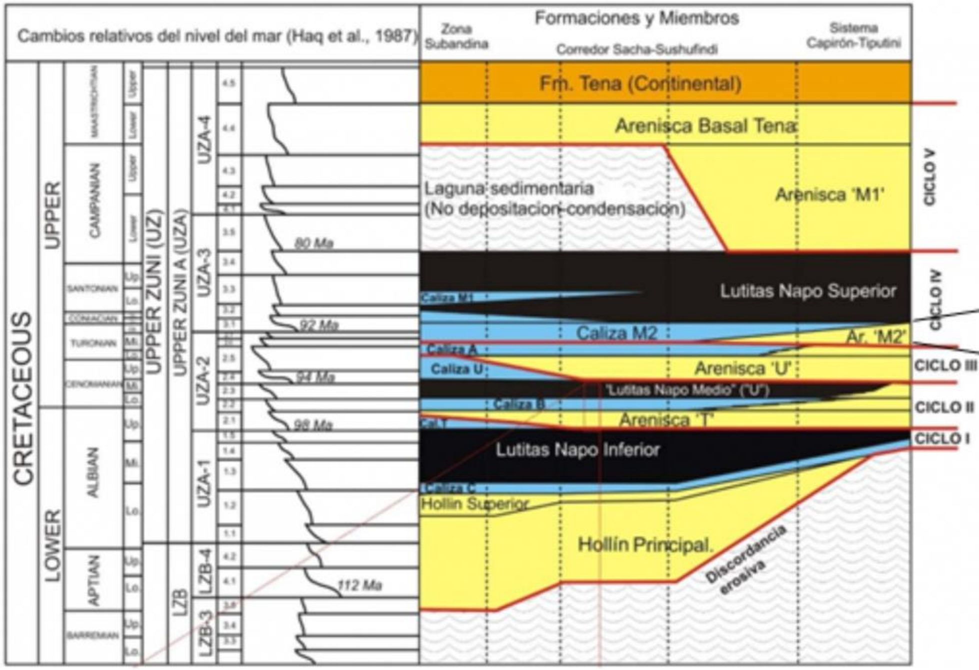
Started Production October 2002

131 active wells @ May-2017

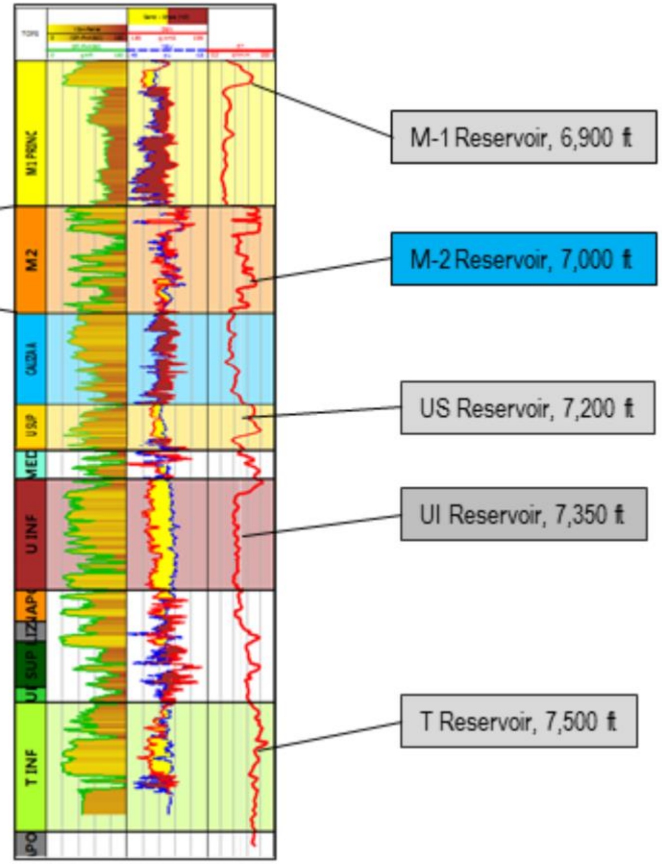
Current Production: 34,500 BOPD

Cumulative Oil Production: 252 MM BLS

Field overview

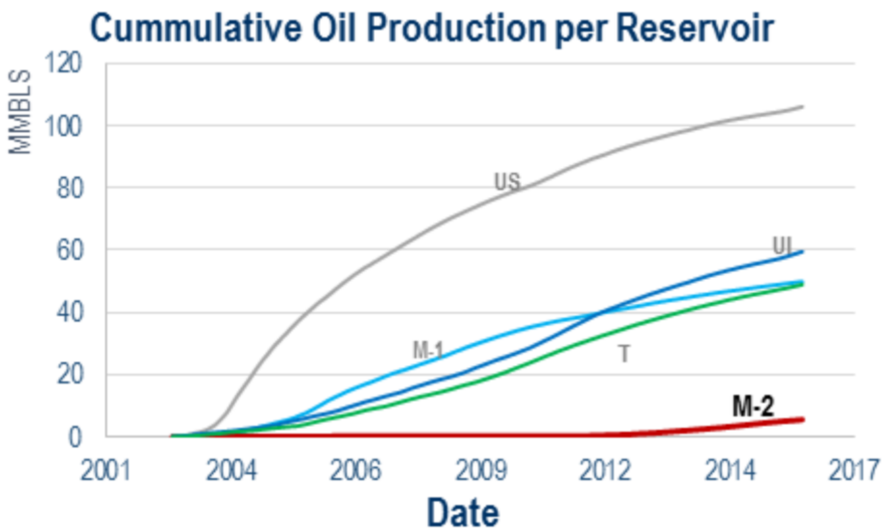


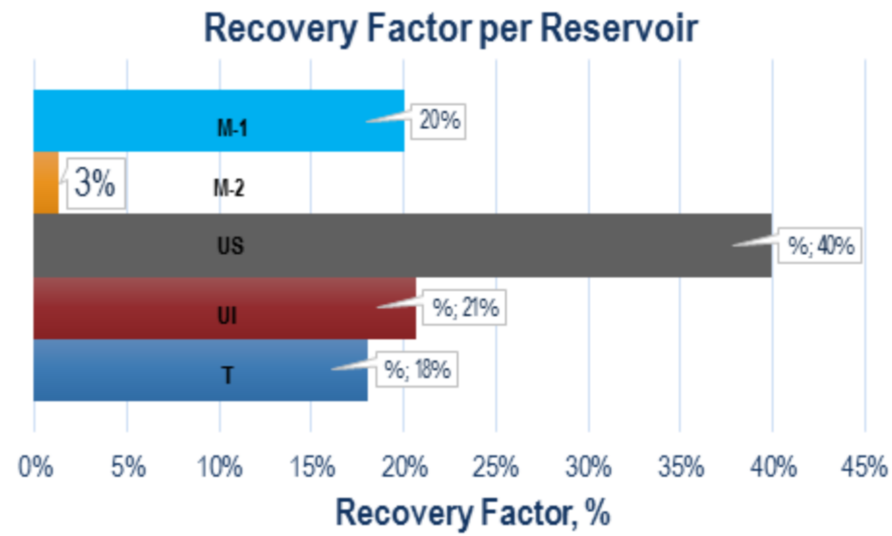
Baby, P., Rivadeneira, M., and Barragan, S. (2014). Geología de la Cuenca Oriente.



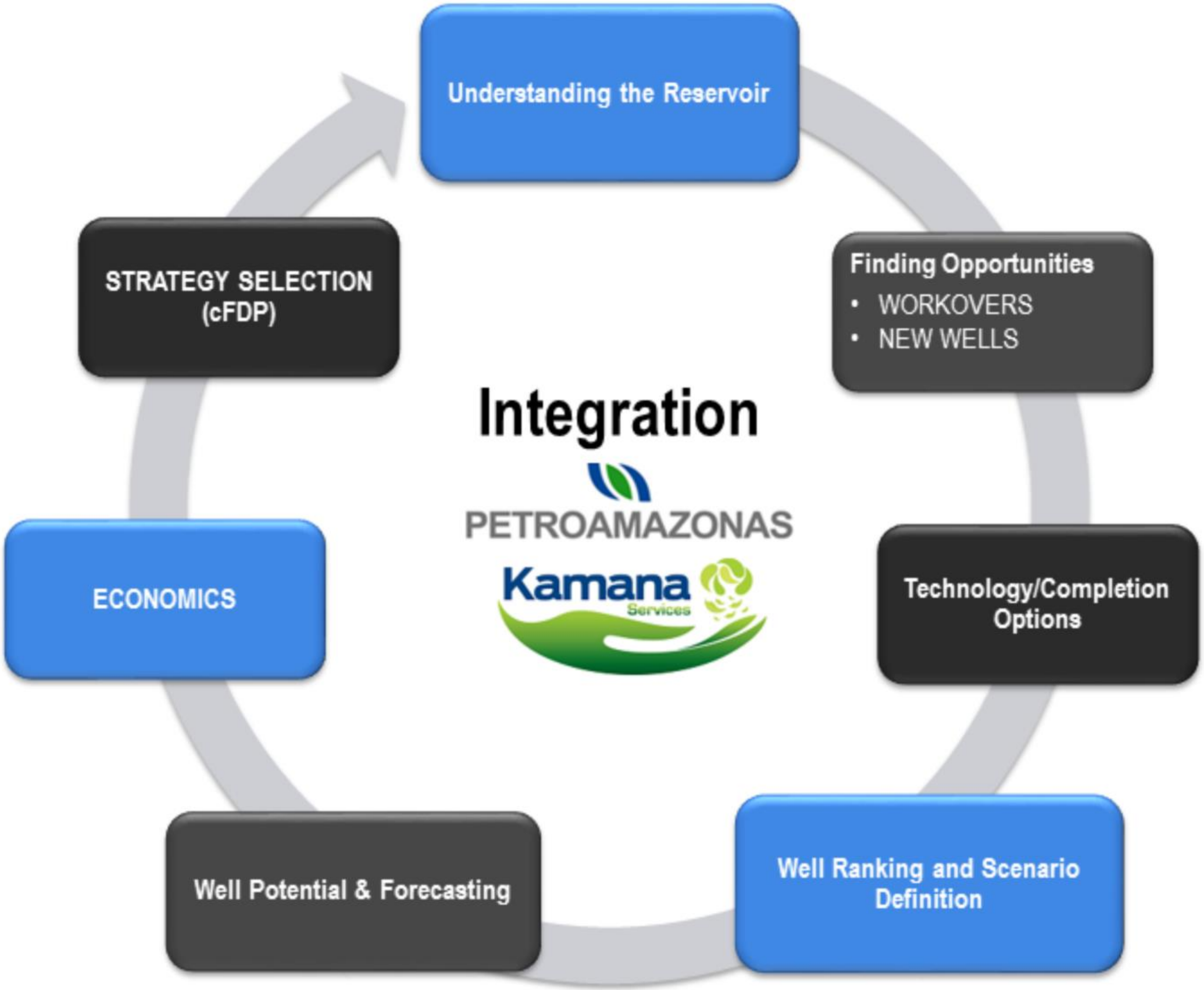
Field overview

Project opportunity





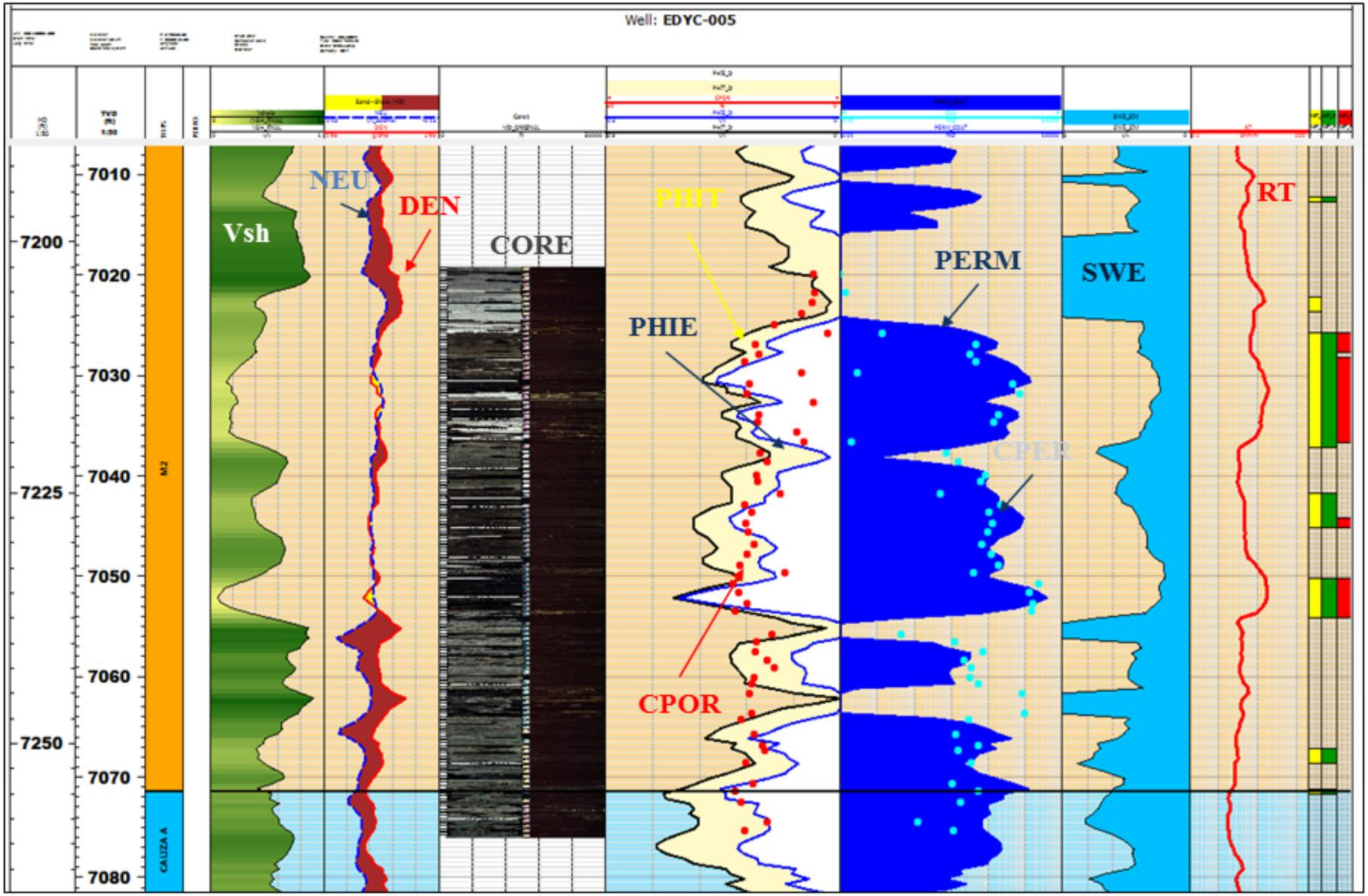
Project development



M-2 RESERVOIR DESCRIPTION

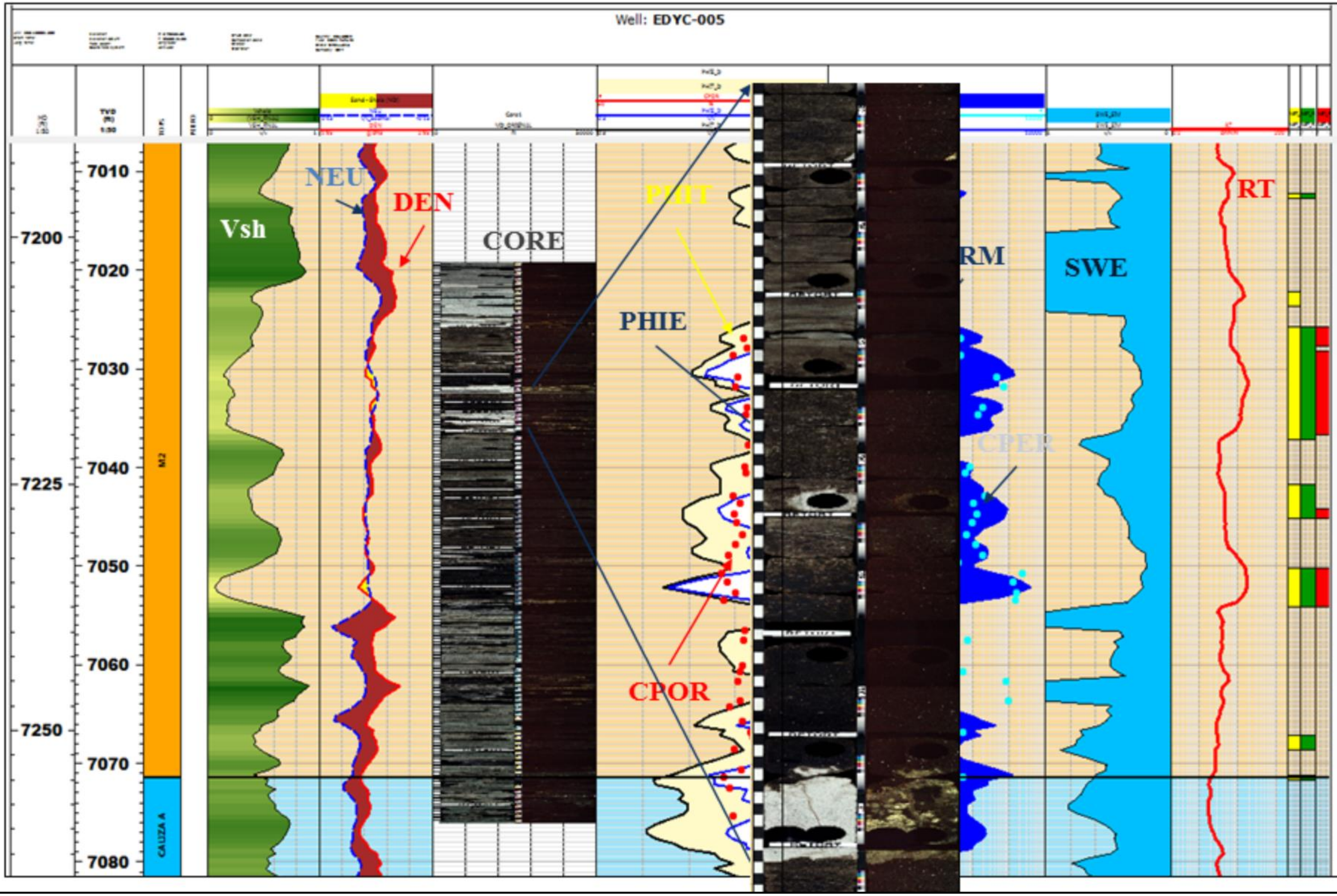
M2 reservoir description

Core EDYC-005

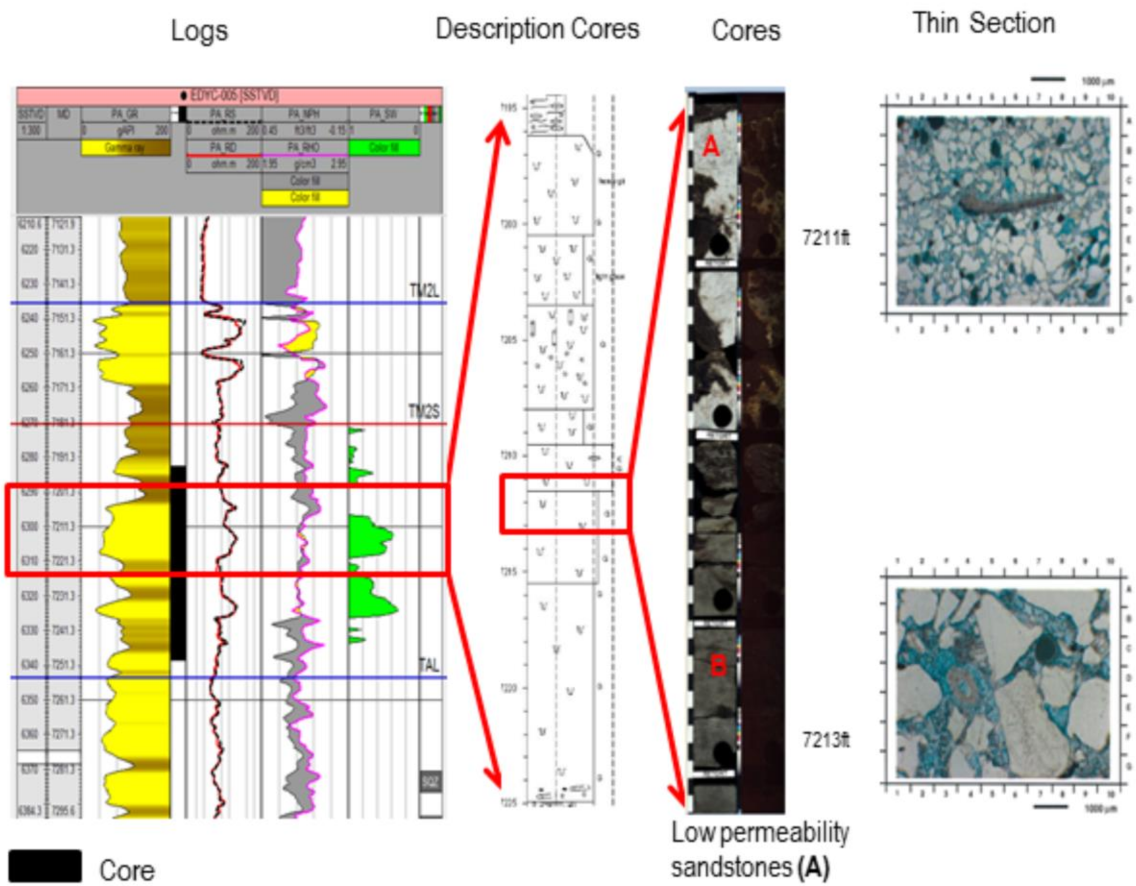


M2 reservoir description

Core EDYC-005



Diagenetic processes affecting reservoir quality



Low permeability sandstones **(A)** alternating with impregnated oil sandstones **(B)**

Shows "A"
Depth. 7207.3 ft
Phi = 5.8%
K =0.003 mD

Fine grained siltstone with Diagenetic Calcite and Glauconite

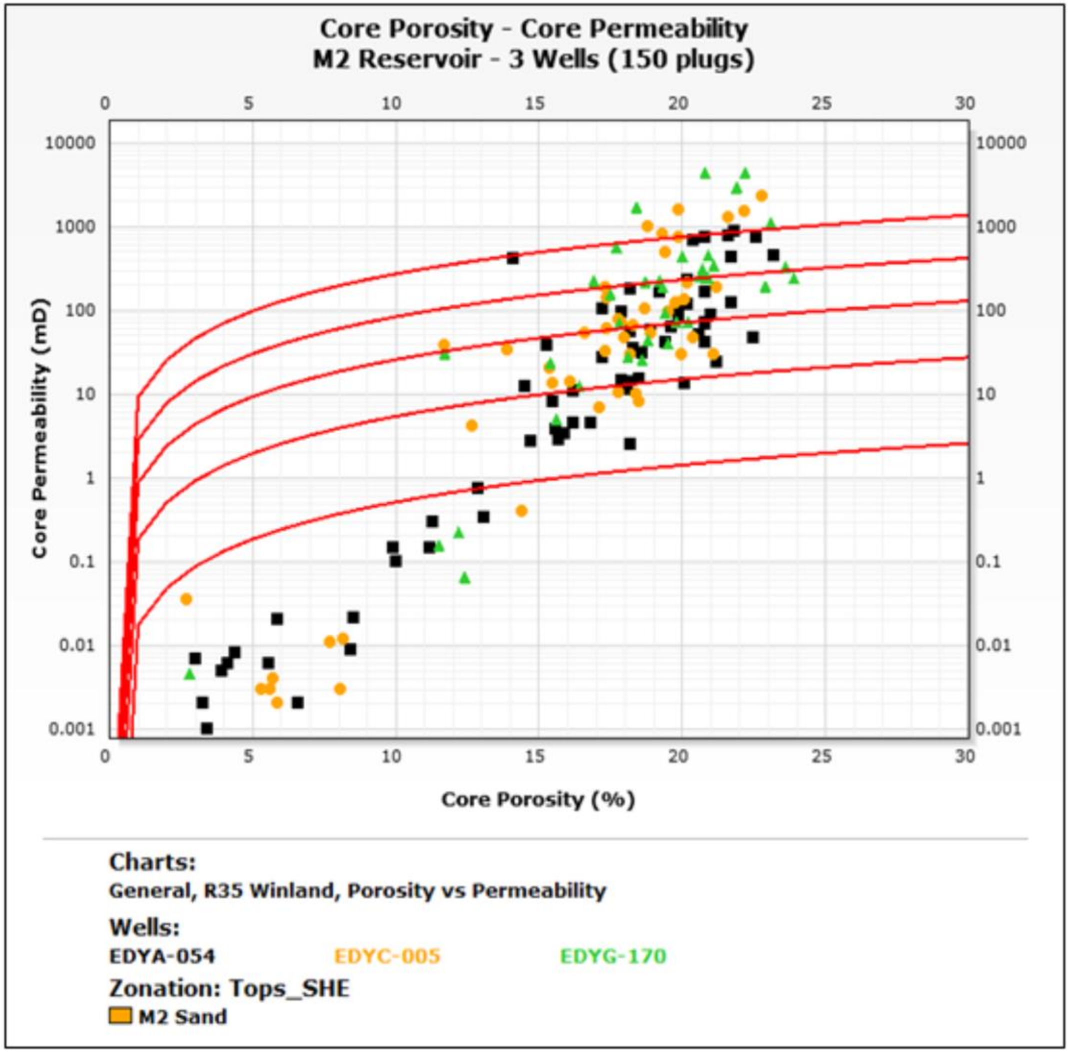
Shows "B"
Depth 7214.5 ft
M2 sand quartzarenite
Phi = 18.4%
Kl = 300mD

Coarse grained siltstone Without diagenetic material similar To T and U reservoirs.

Presenter's notes : Core description show that diagenetic process has degraded M-2 Reservoir Quality by the presence of Calcite and Glauconite.
We can see the difference in the core, Point B has a good reservoir quality by other hand the point A show the degradation of the M-2 reservoir.

Cross Plot M-2 (Core Porosity vs Core Permeability)

PETROAMAZONAS | Kamana Services



- Wide ranges in permeability for a narrow porosity ranges.
- Diagenetic process (calcite and glauconite) have degraded the quality of reservoir bodies

High vertical heterogeneity and low connectivity

Presenter's notes : We have Wide ranges in permeability with low range in porosity. It confirms the varied and layered reservoir quality.
From this point of view, It is necessary to improve productivity by increasing the flow capacity through fractures that allow a better connection between the pores and between layers of quartz sandstones.
The best technique to interconnect thin layers is Hydraulic fracturing.

EDYG-170: Arenisca M2 rock mechanics

Core Lab

TRIAXIAL COMPRESSIVE TEST RESULTS

Company	Petroamazonas	Date	Jan. 2014
Well Name	EDYG-170	Job No.	HOU-140005
Field Name		Saturation Fluid	3% KCl
Location	Ecuador	Rock Type	Sandstone

Table 1 Triaxial Static Young's Modulus, Poisson's Ratio and Compressive Strength

Sample Number	Depth (ft)	Effective Confining Pres (psi)	Bulk Density (gm/cm^3)	Compressive Strength (psi)	Young's Modulus (10^6 psi)	Poisson's Ratio
31V	7823.60	920	2.195	9983	0.96	0.24
27V	7818.90	1830	2.225	14806	2.13	0.23
40V	7853.60	2750	2.284	17668	2.91	0.24

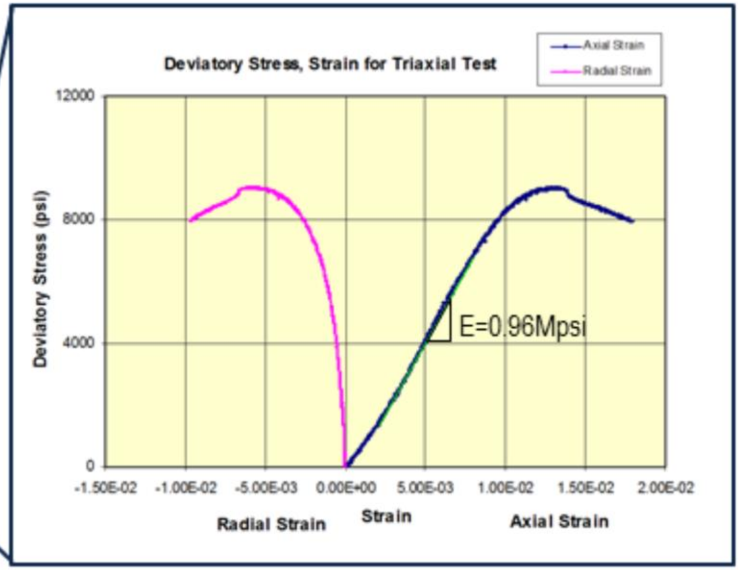
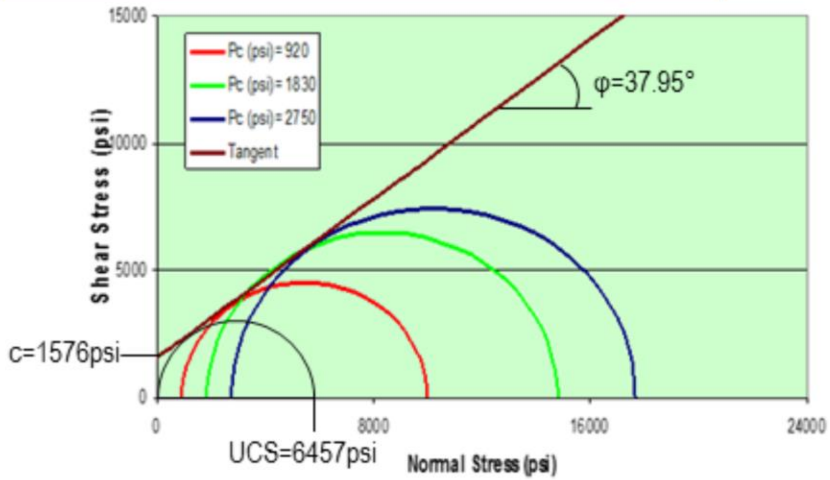
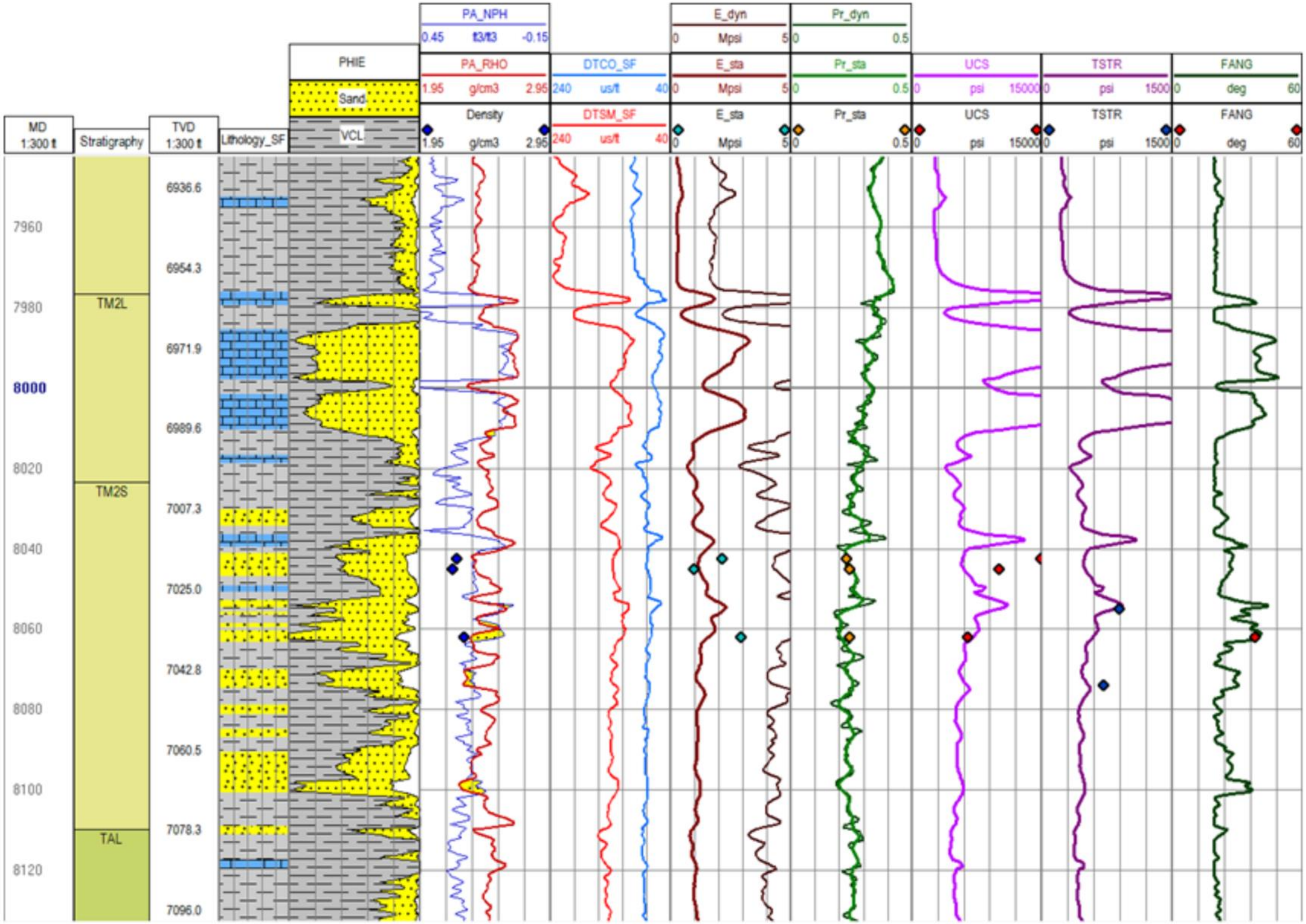


Table 2 Results of Mohr-Coulomb Failure Analysis

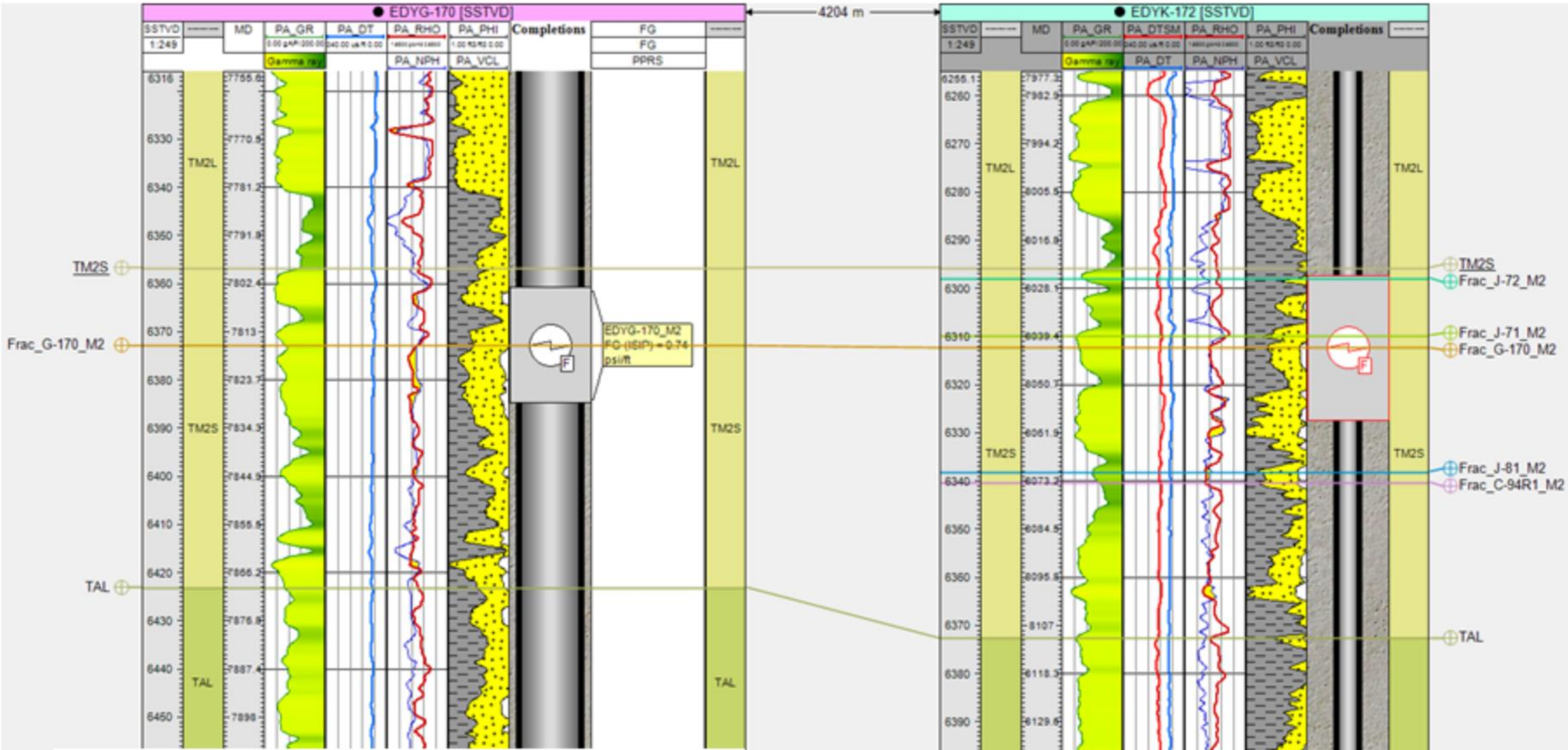
Sample Depth (ft)	Confining Pressure $P_c = \sigma_3$ (psi)	Compressive Strength σ_1 (psi)	Slope on σ_1 vs. σ_3	Unconfined Compressive Strength (psi)	Cohesion (psi)	Angle of Internal Friction	Coefficient of Internal Friction
7823.60	920	9983					
7818.90	1830	14806					
7853.60	2750	17668	4.20	6457	1576	37.97	0.78



EDYK-172: rock properties in M2



Hydraulic fracturing limits



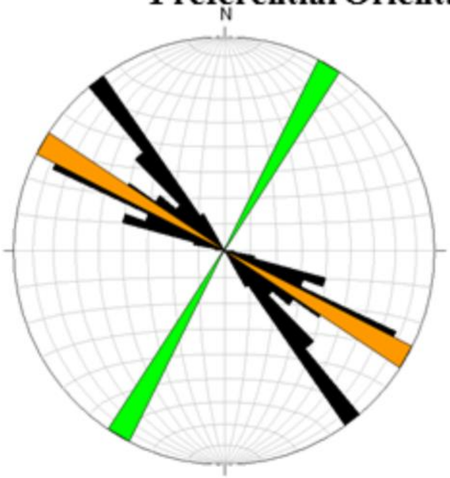
BreakDown Pressure Psi

Well	loLim	UpperLim	Well_test_before_frac
EDYF097	6400	6900	N
EDYC-094		7700	Y
EDYF-117	7200	7900	N
EDYG-170		7000	N

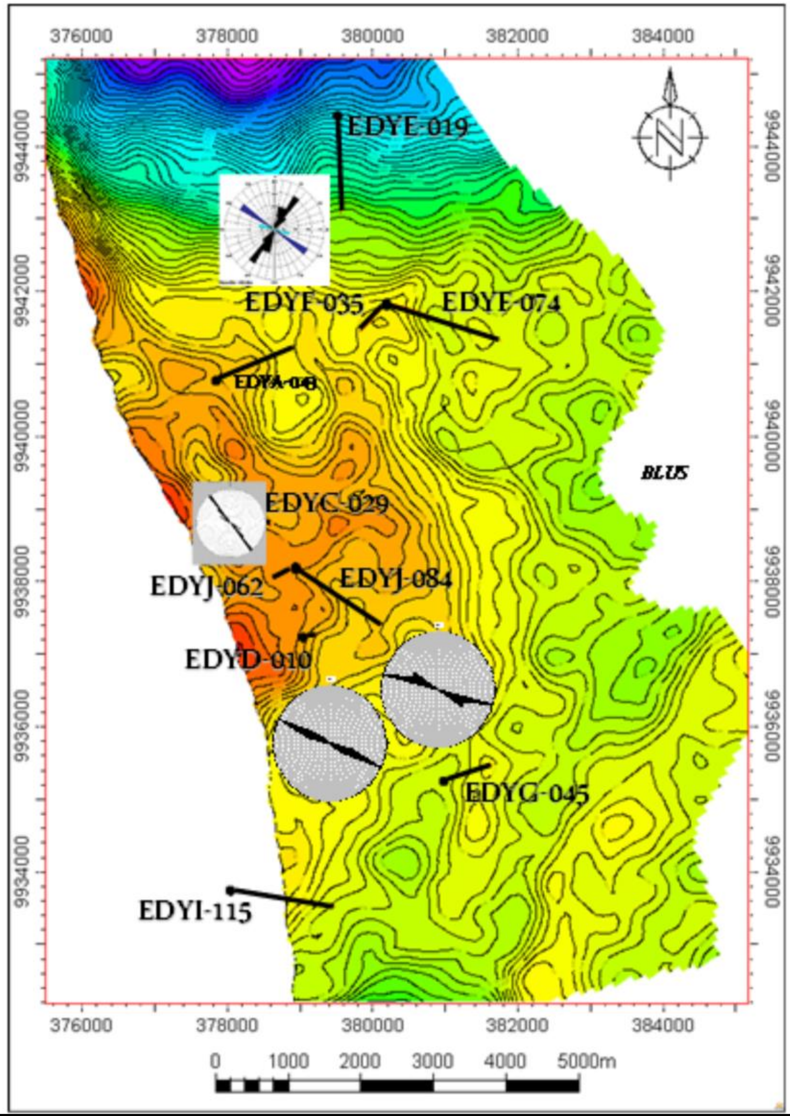
Pozo	Date	Reservoir	CG_psi /ft	FG ISIP (psi / ft)
EDYJ-081	2011-07-15	M2	0.57	**0.43**
EDYJ-072	2013-07-05	M2	0.736	**0.88**
EDYJ-071	18-10-2013	M2	0.685	**0.7**
EDYG-170	31-01-2014	M2	0.685	**0.74**
EDYC-094R1	17-01-2015	M2		**0.76**

Geomechanics for M-2 confirmed known stresses

Preferential Orientation



SH_Azim = 120° ± 9
Sh_Azim = 30° ± 9

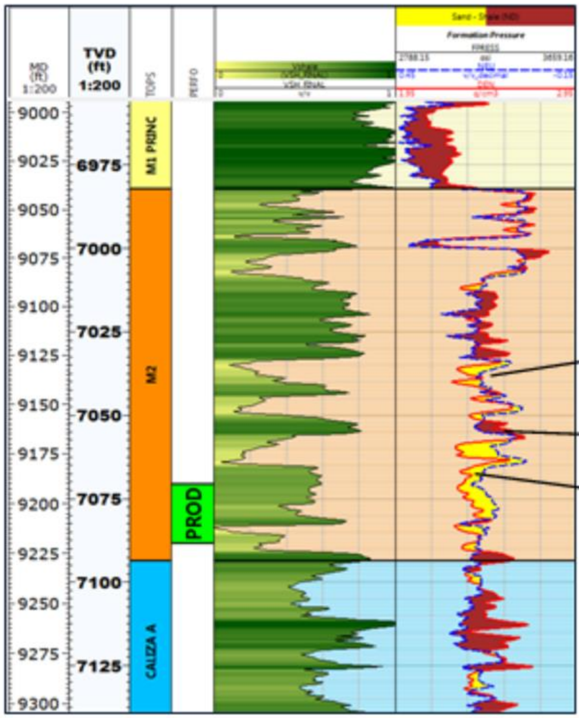


Directional Strain Estimation in M-2 needed to plan for a possible candidate for multi stage frac in Horizontal well in M-2.

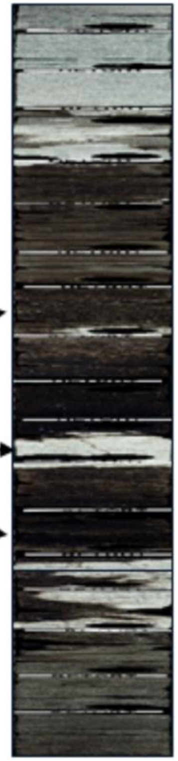
Completion techniques

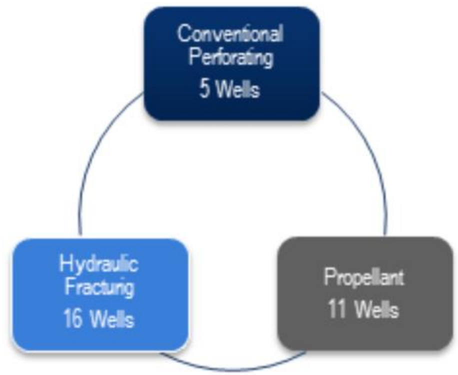
PROJECT DEVELOPMENT – Technology / Completion Options

EDYK-167S1



Challenge Multilayer Reservoir



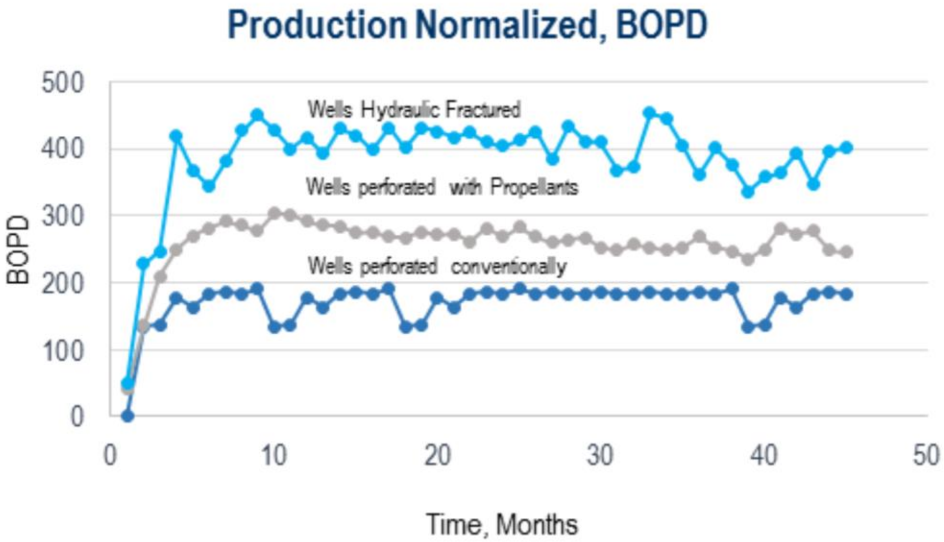


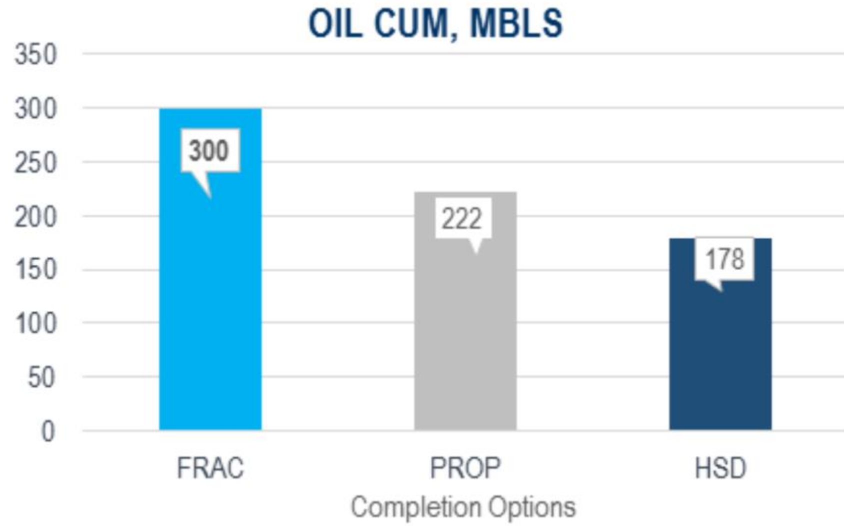
Presenter's notes : Due to the layering characteristic of M-2 completion strategy should be address to connect those layers. Historically M-2 wells have been hydraulic fractured, perforated with propellant and conventional perforating, results of each technology apply were analyzed in 16 wells HF, 11 Prope, 5 wells Conv Perf.

Completion techniques

PETROAMAZONAS | Kamana Services

PROJECT DEVELOPMENT – Productivity Behavior





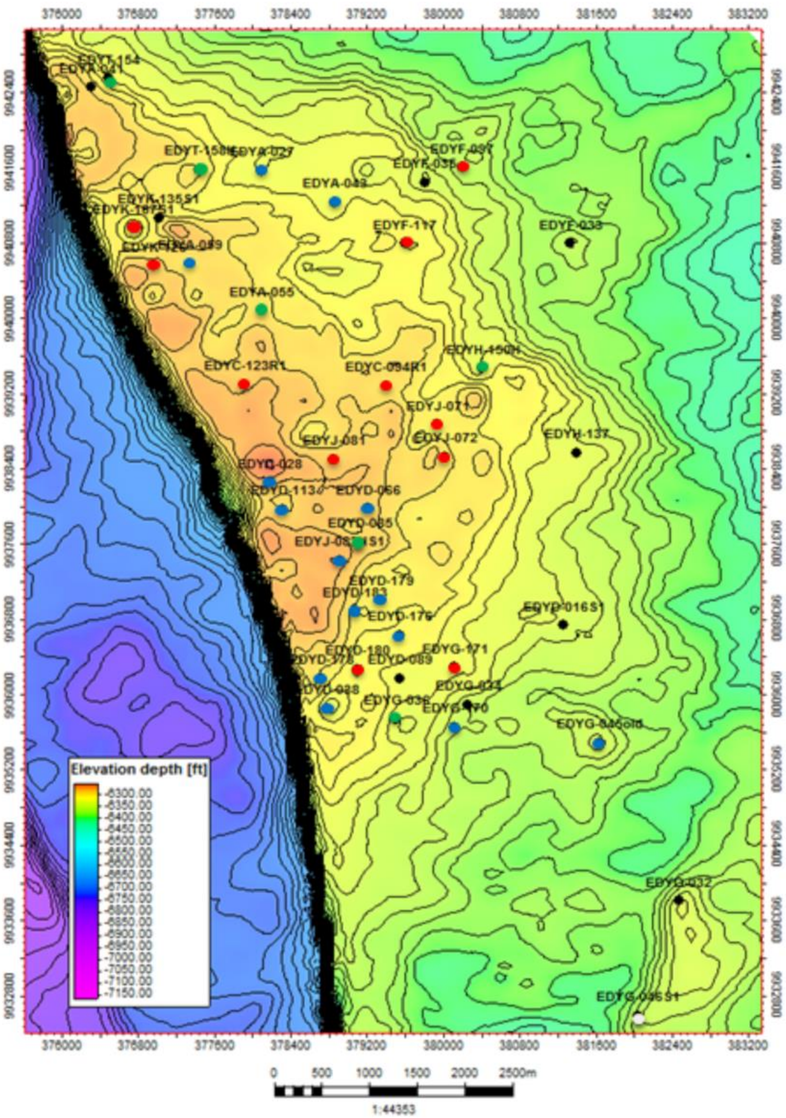
Presenter's notes : Graph on the left shows historical production profile by technology. Normalized date indicate an average of 180 bls per day with conventional perforating which represent 178 mbls of cumulative oil production. When the well is perforated with propellant the average production is 250 bopd with a 200 mbls of cumulative production. And the third technology applied which is HF shows an average of 430 bopd with a cumulative production of 300 mbls. These results lead to choose hydraulic fracture as the best completion technique.

DEVELOPMENT & OPTIMIZATION

Development & optimization

PETROAMAZONAS

Kamana Services



- 12 Hydraulic Fractured
  - 5 Wells previously fractured
  - 7 wells executed
- 13 perforated with propellants
- 8 HSD perforation
- 7 more frac jobs planned.

- Frac wells
- Propellant
- HSD perforation
- Planned workover

Presenter's notes : To date, 33 wells have been completed in M-2, where, 12 were hydraulic fractured, 13 perforated with propellants, with high shot density perforation and 7 Planed Workovers to 2015 Hydraulic Fracturing has commonly been applied in Ecuador as an alternative to reduce formation damage, requiring a pre and post-frac evaluation.

Planed Workover

EDYD-085

EDYG-036

EDYG-046S1

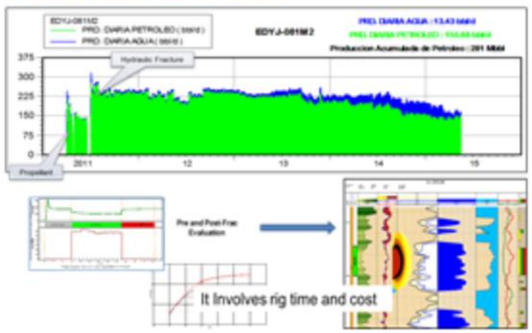
EDYH-150H

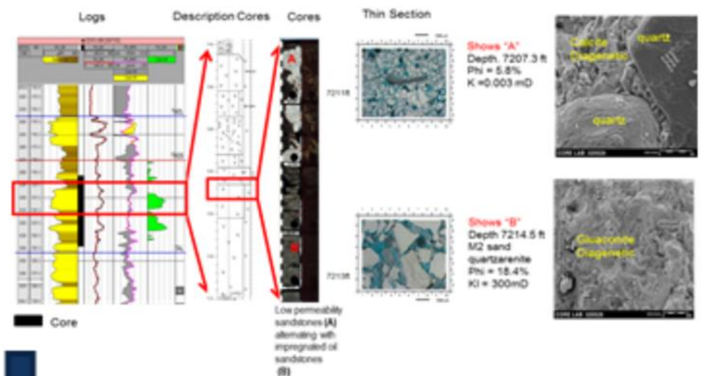
EDYT-154

EDYT-158

Development & optimization

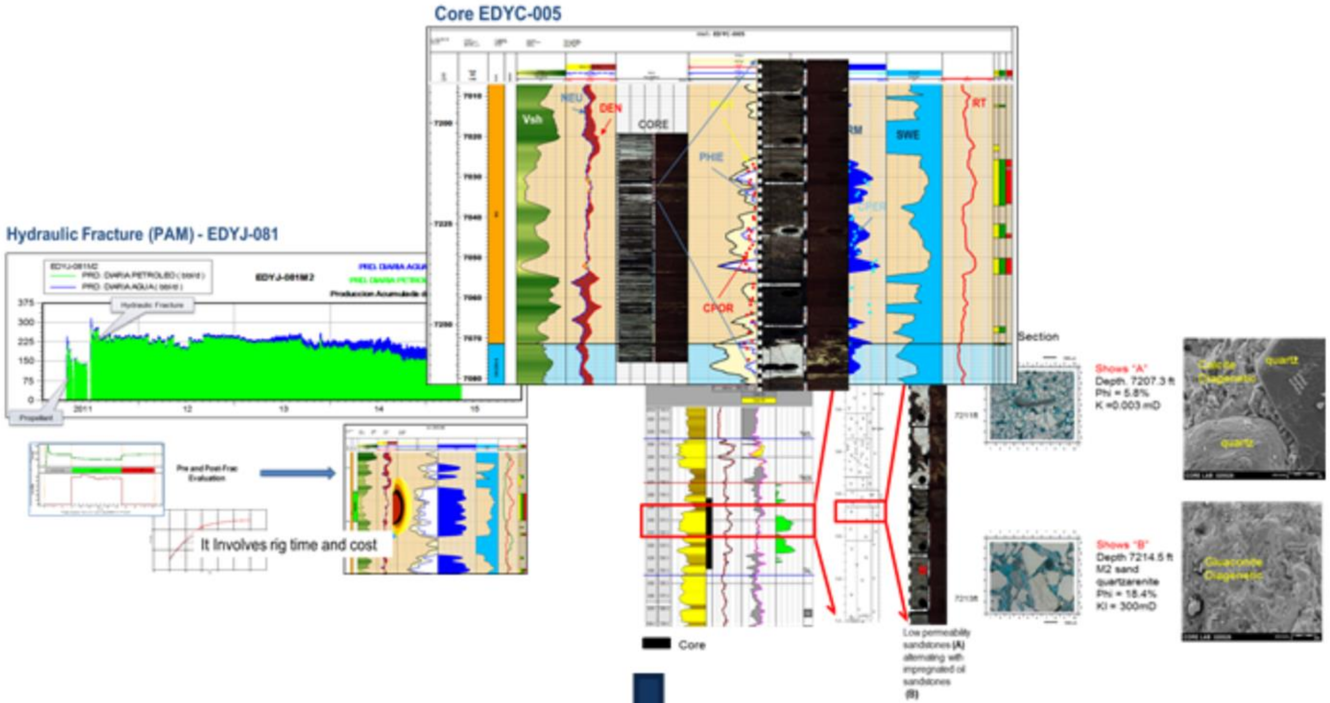
Hydraulic Fracture (PAM) - EDYJ-081





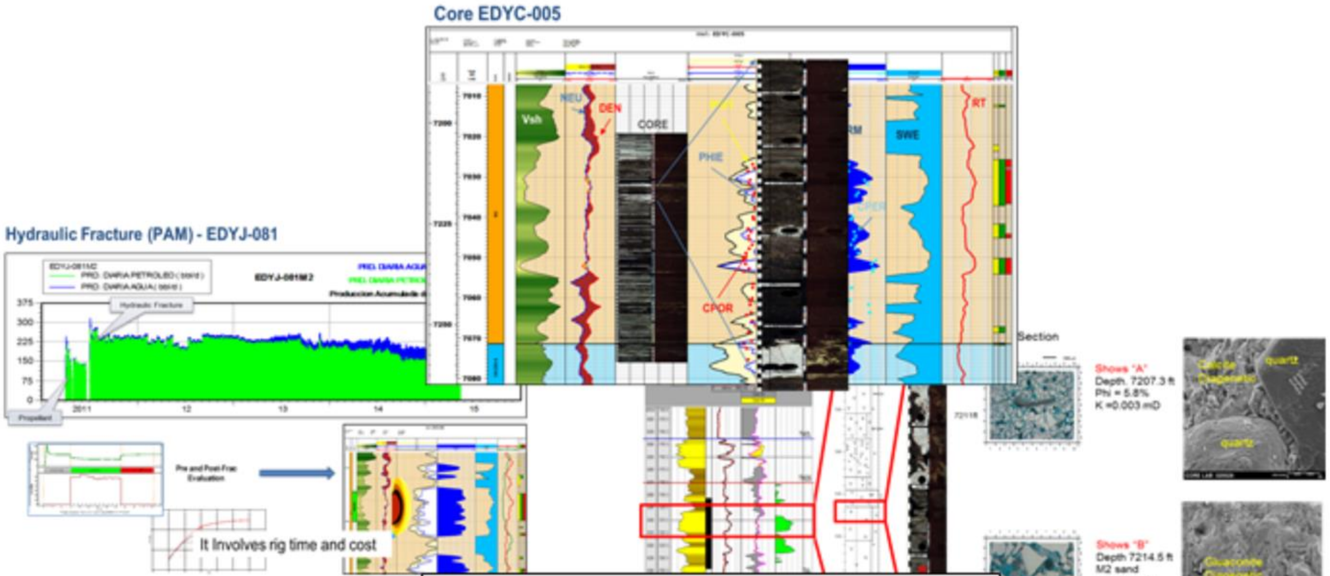
Ecuadorian regulatory agency approved Hydraulic Fracture Jobs without a Pre and Post – Frac Evaluation for M-2 laminated Reservoir.

Development & optimization



Ecuadorian regulatory agency approved Hydraulic Fracture Jobs without a Pre and Post – Frac Evaluation for M-2 laminated Reservoir.

Development & optimization

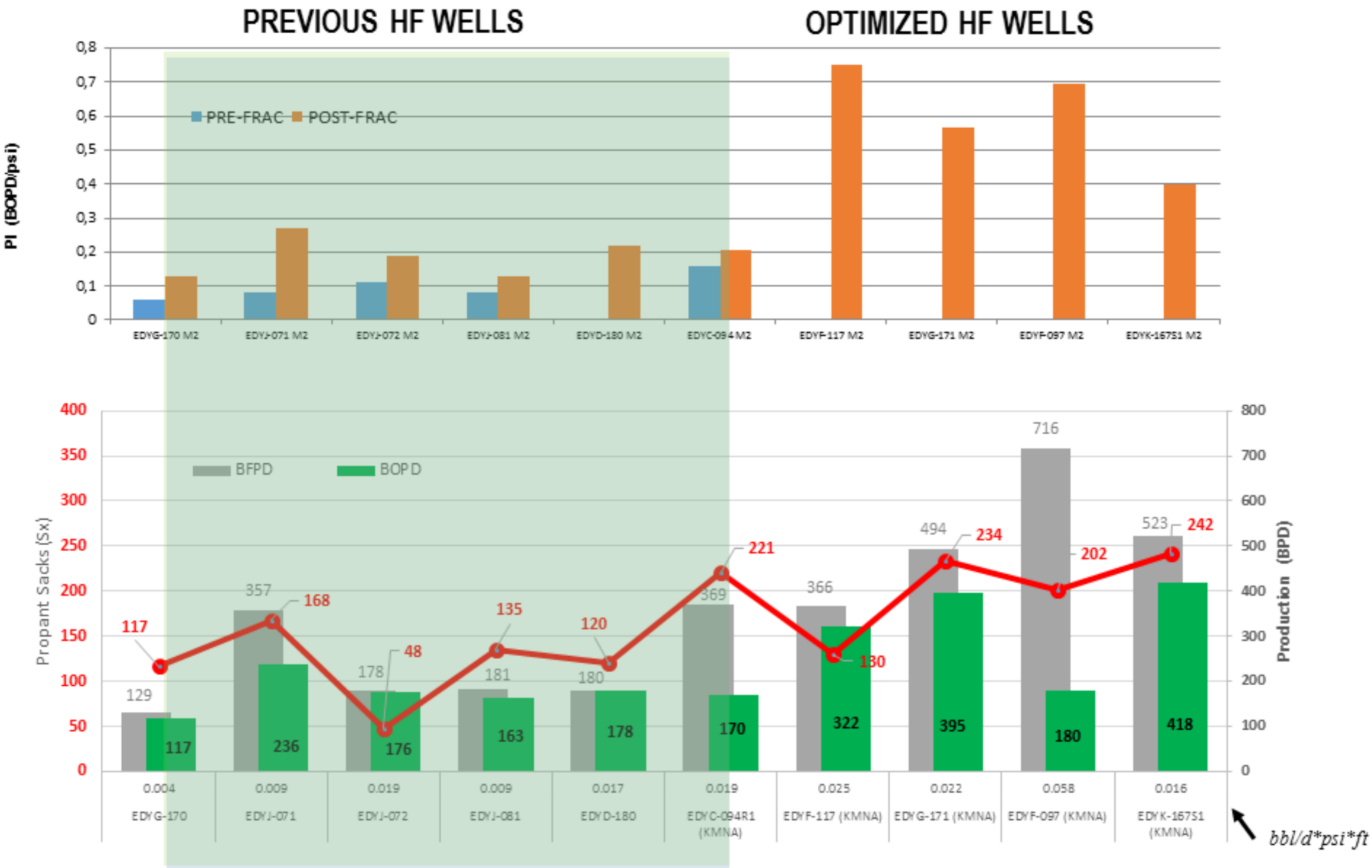


Reduction in operative costs
and deferred production

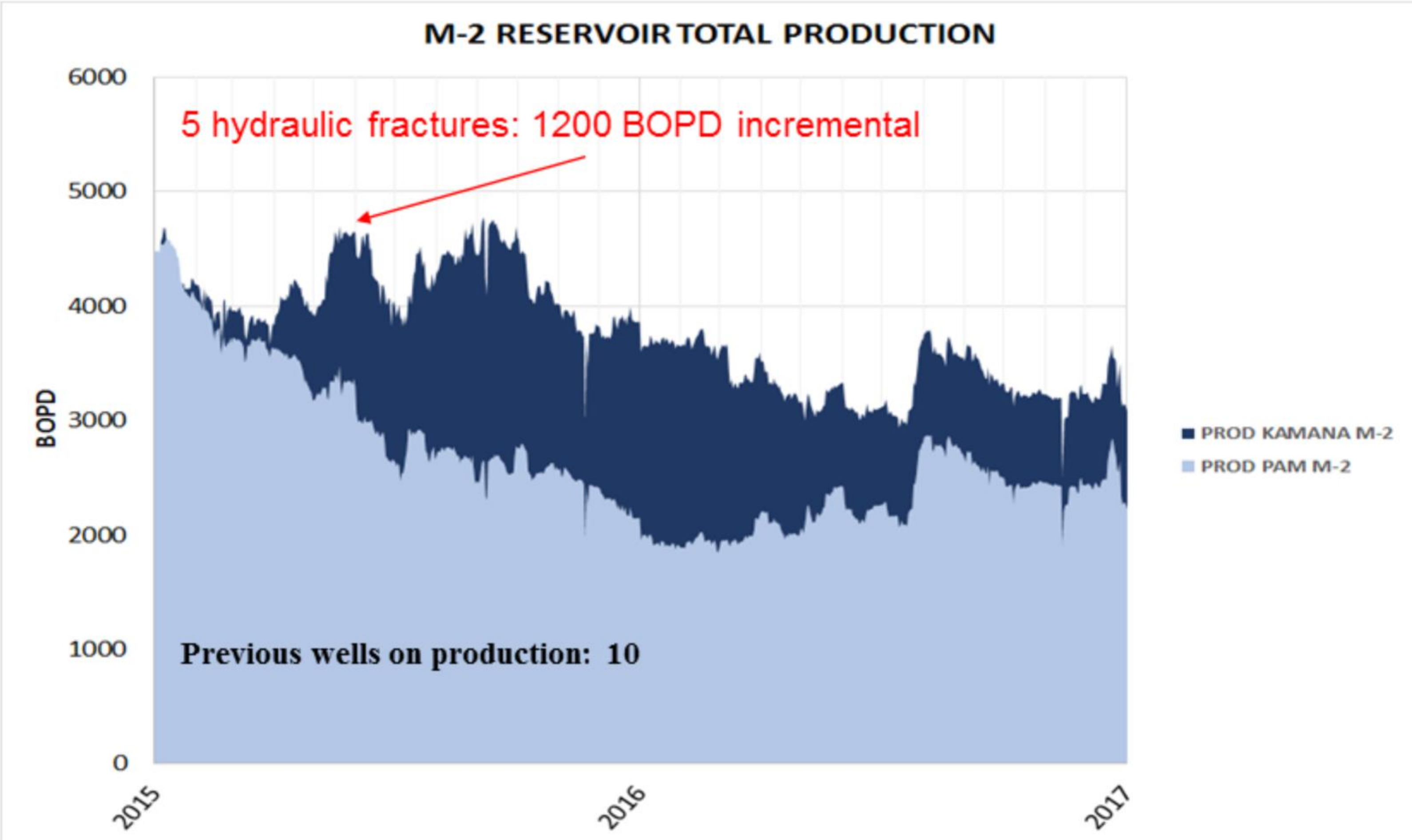
Ecuadorian regulatory agency approved Hydraulic Fracture Jobs without a Pre and Post – Frac Evaluation for M-2 laminated Reservoir.

Productivity Index Statistics and Hydraulic Fractured Evolution

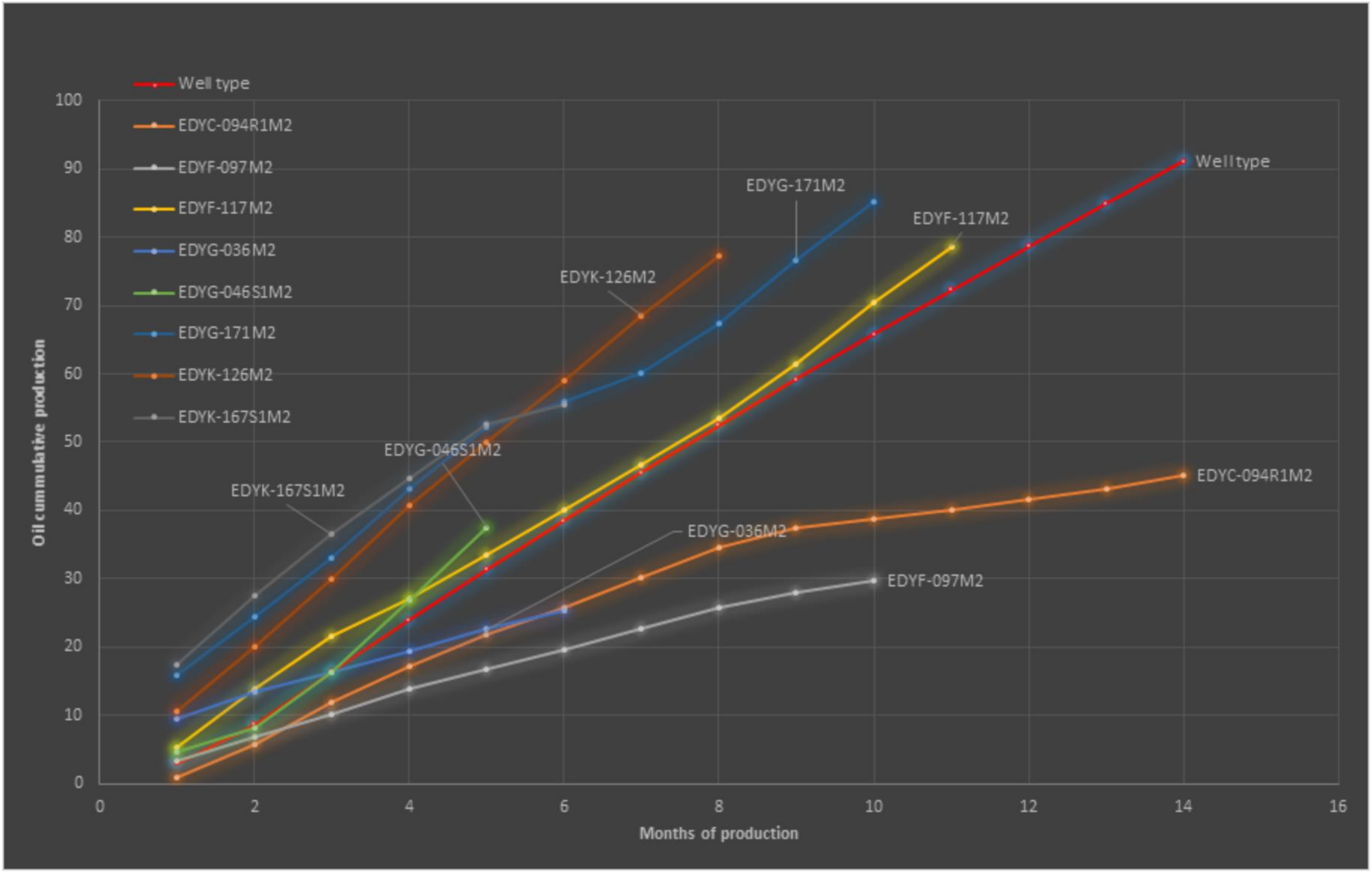
PETROAMAZONAS
Kamana Services



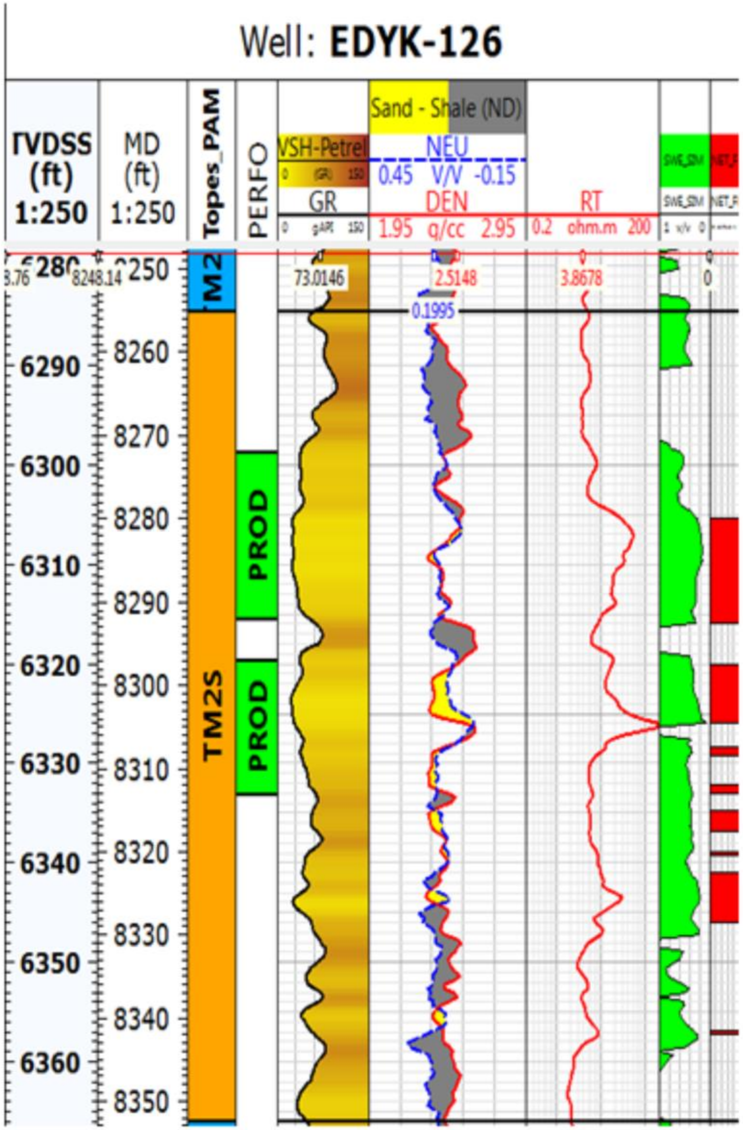
M-2 2015 Workover Results Production

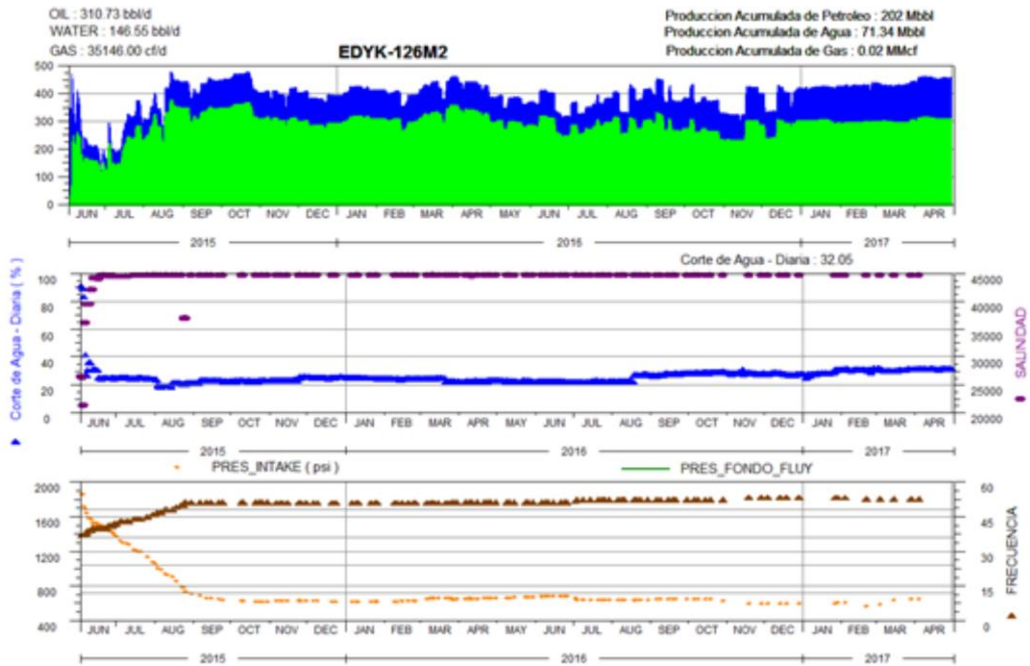


Hydraulic fractured well productivity against well type

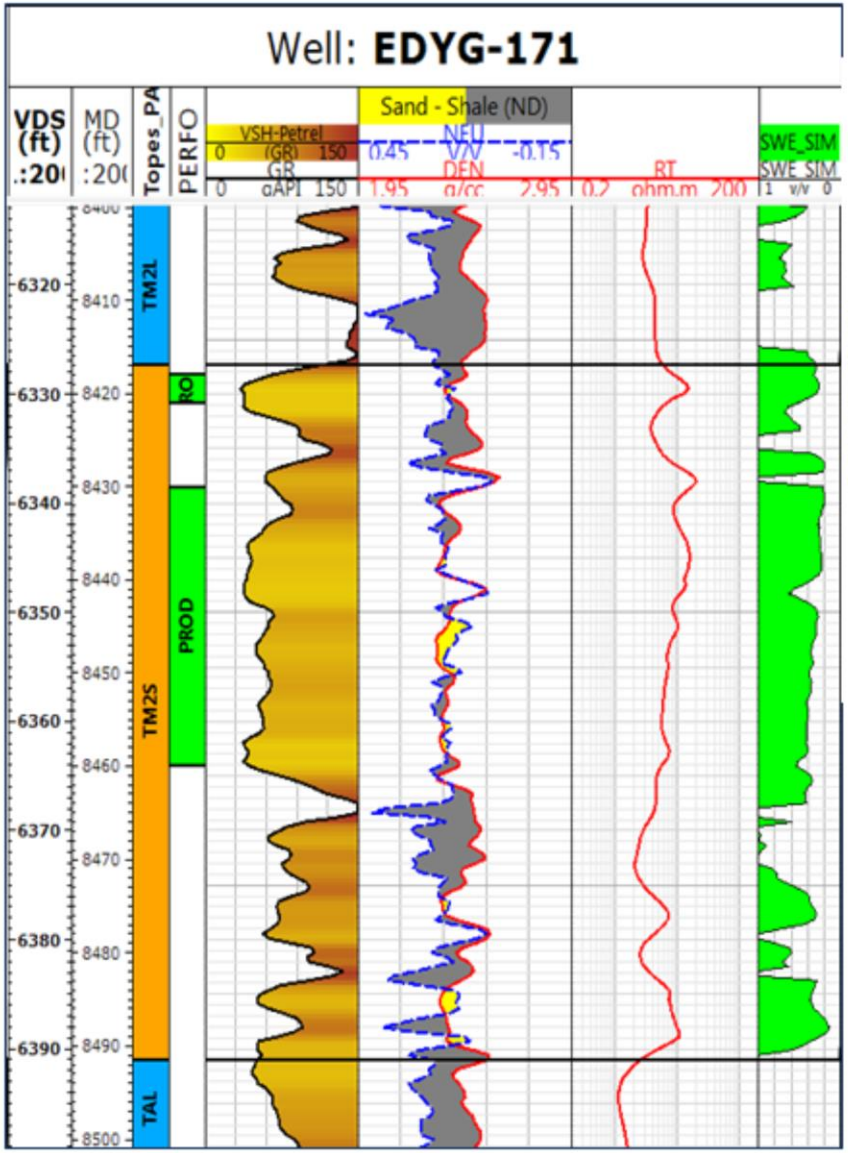


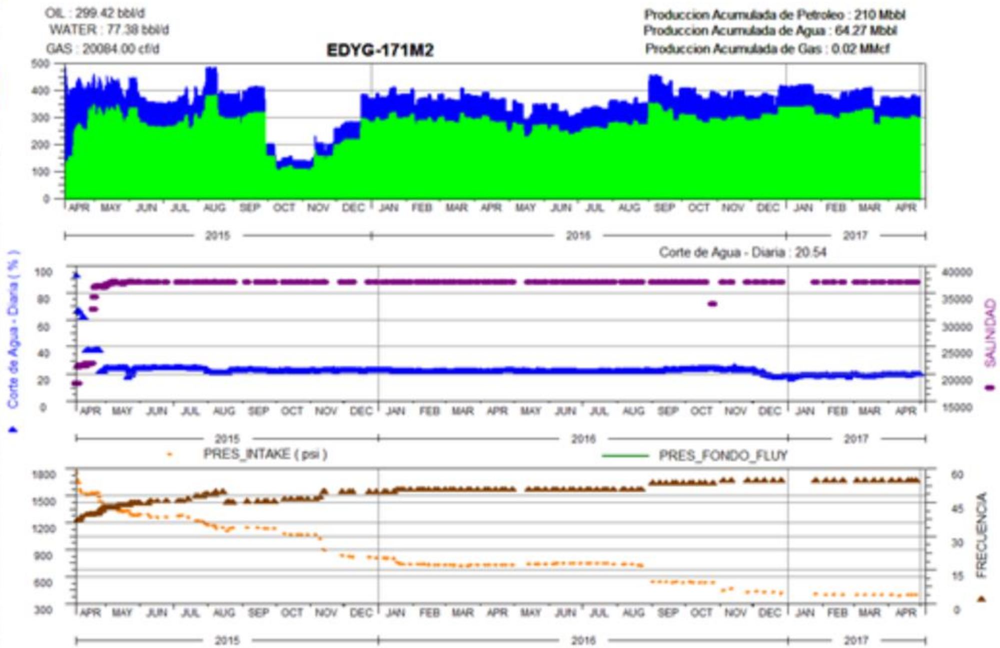
EDYK-126: Hydraulic fracture



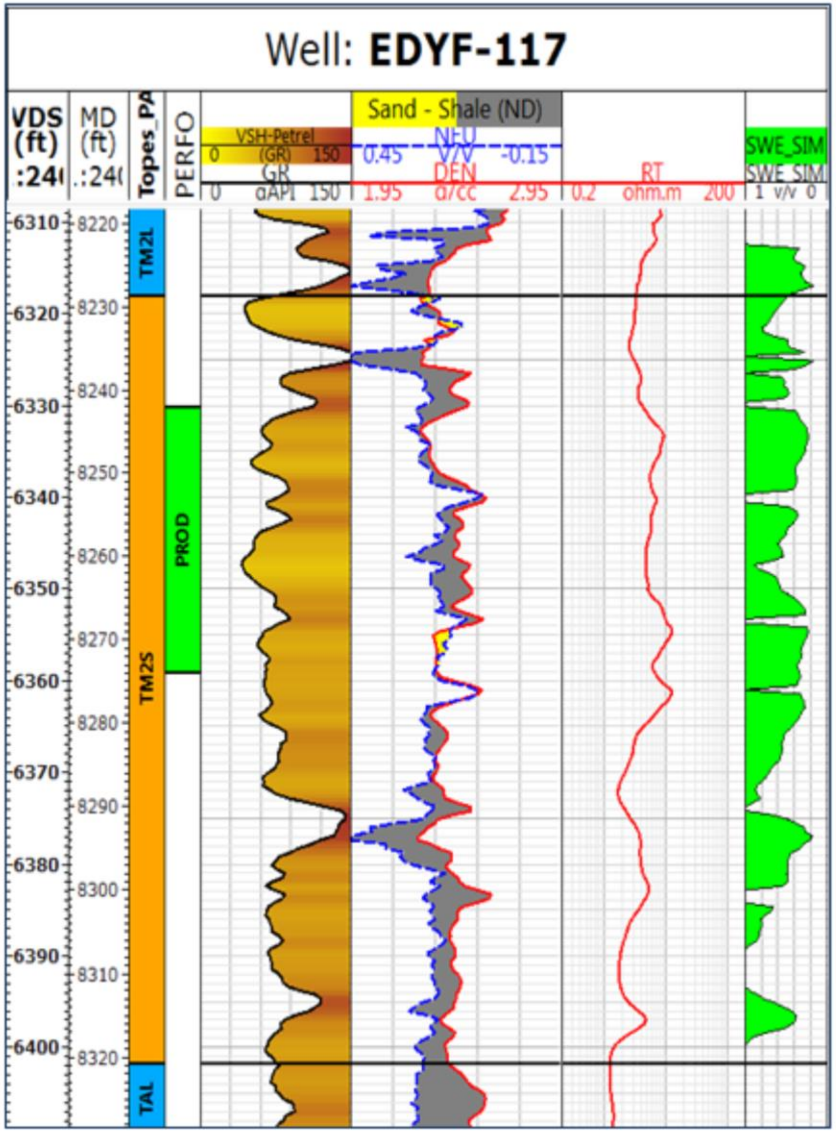


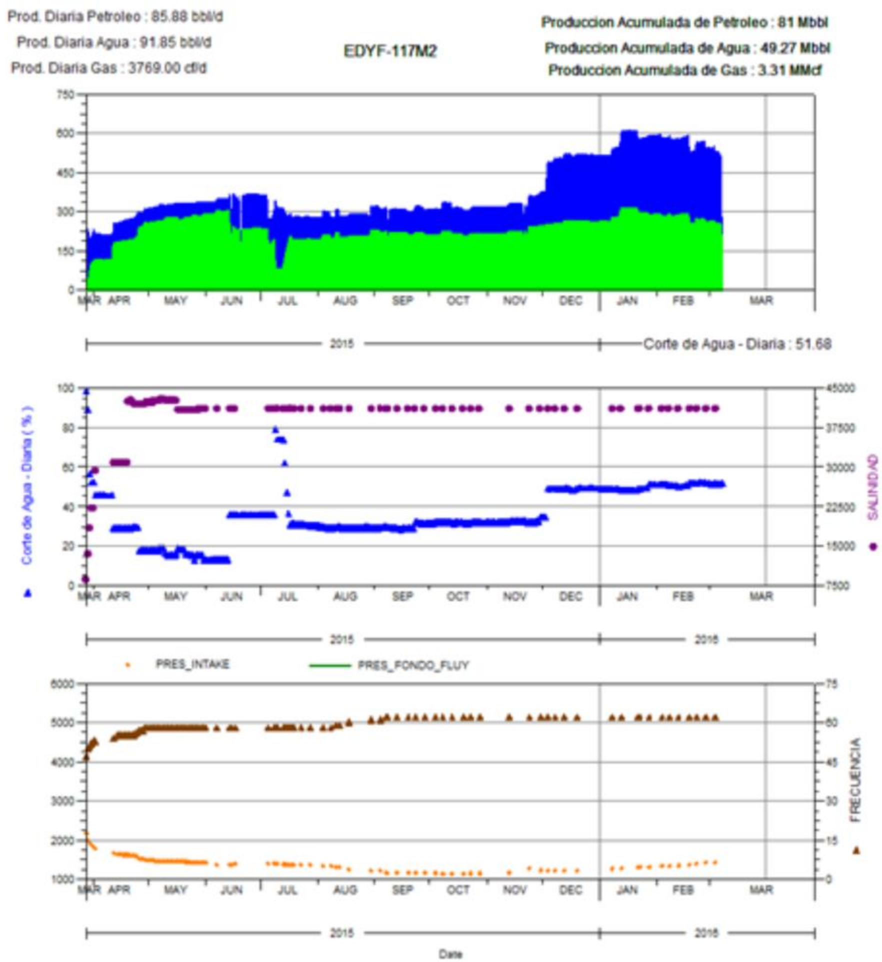
EDYG-171: Hydraulic fracture





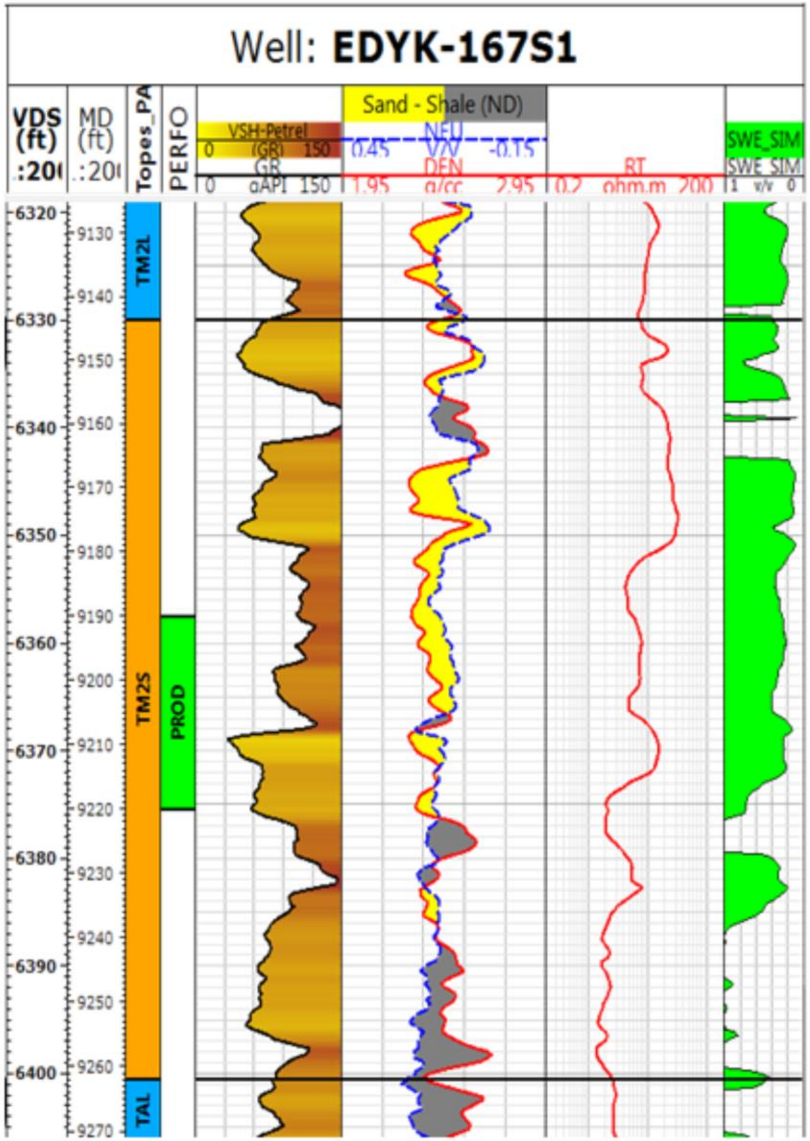
EDYF-117: Hydraulic fracture

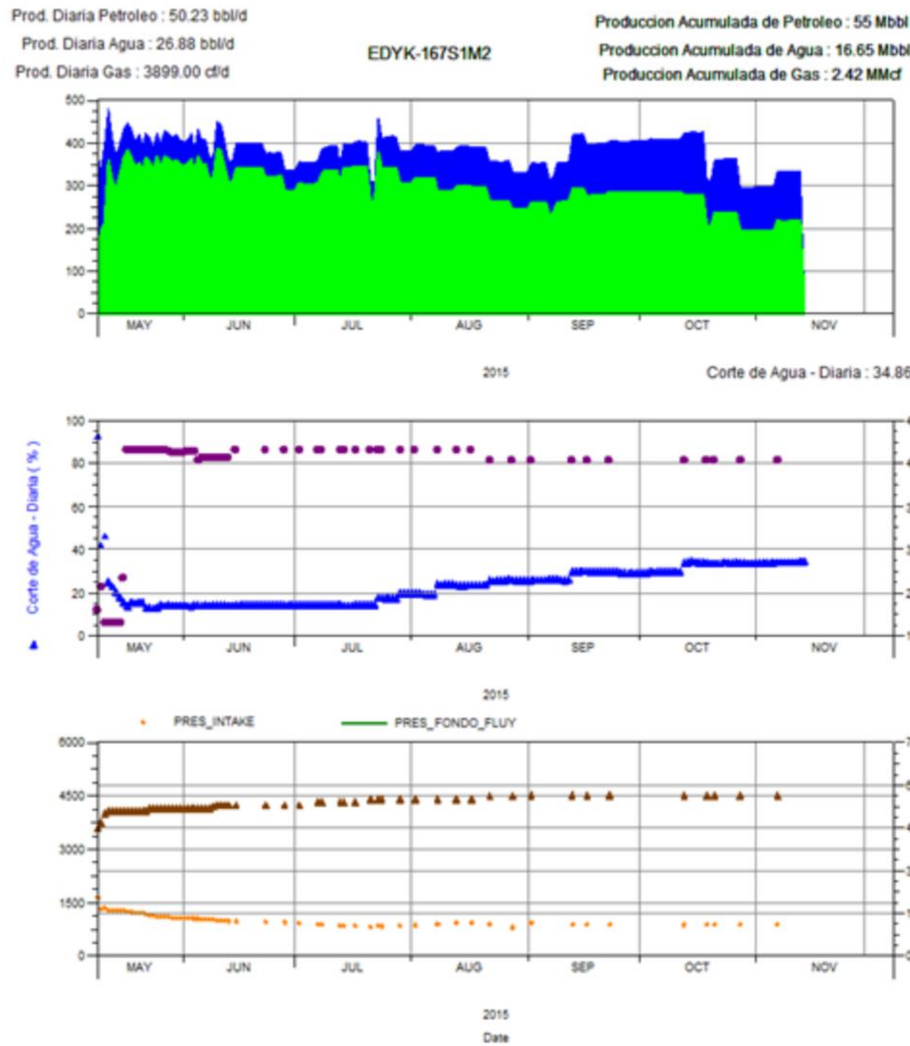




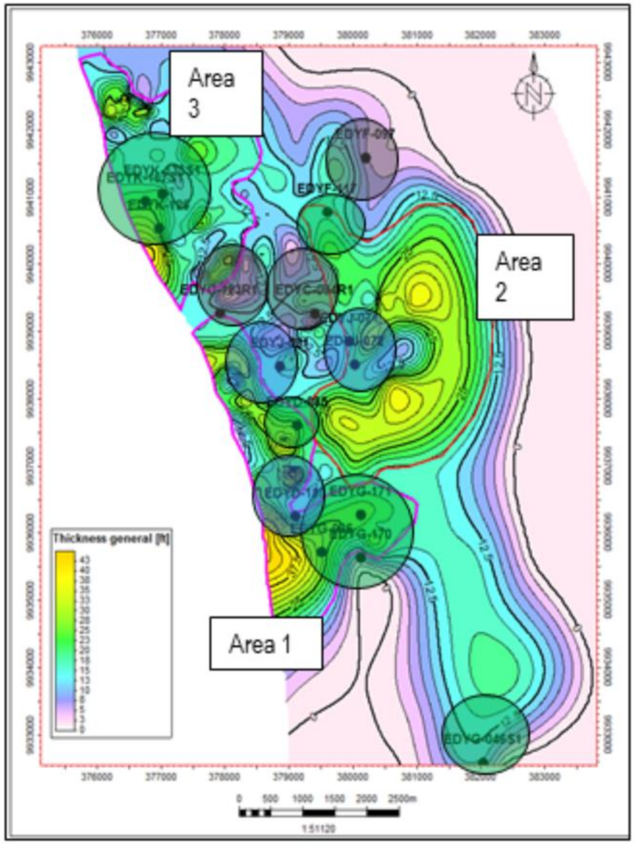
EDYK-167S1: Hydraulic fracture

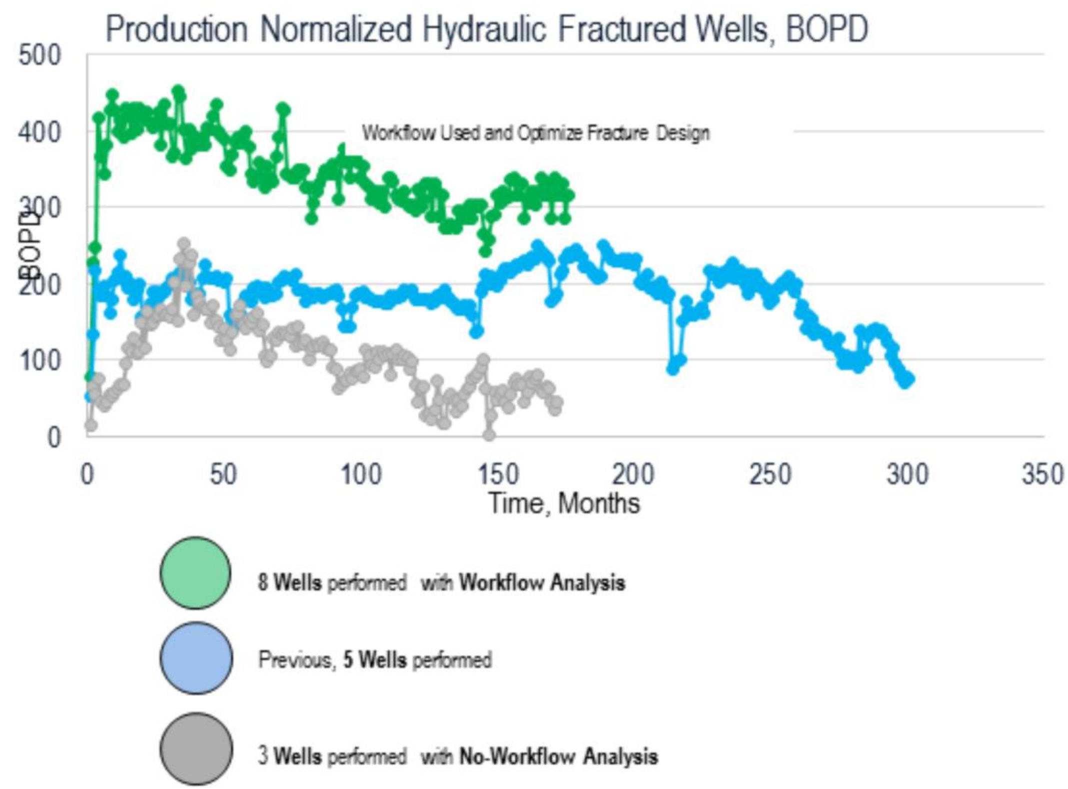
PETROAMAZONAS | Kamana Services



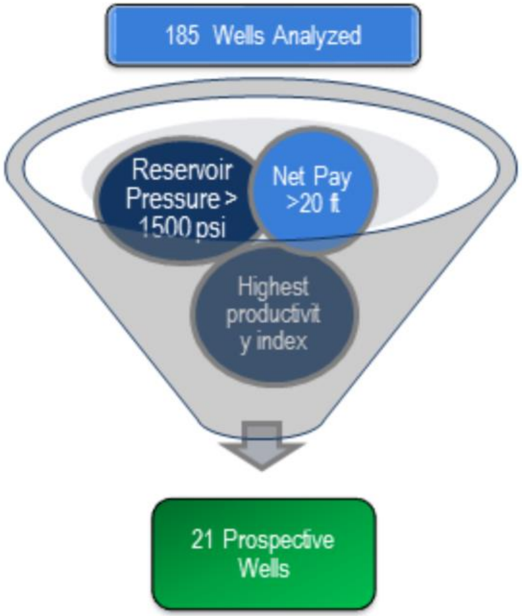


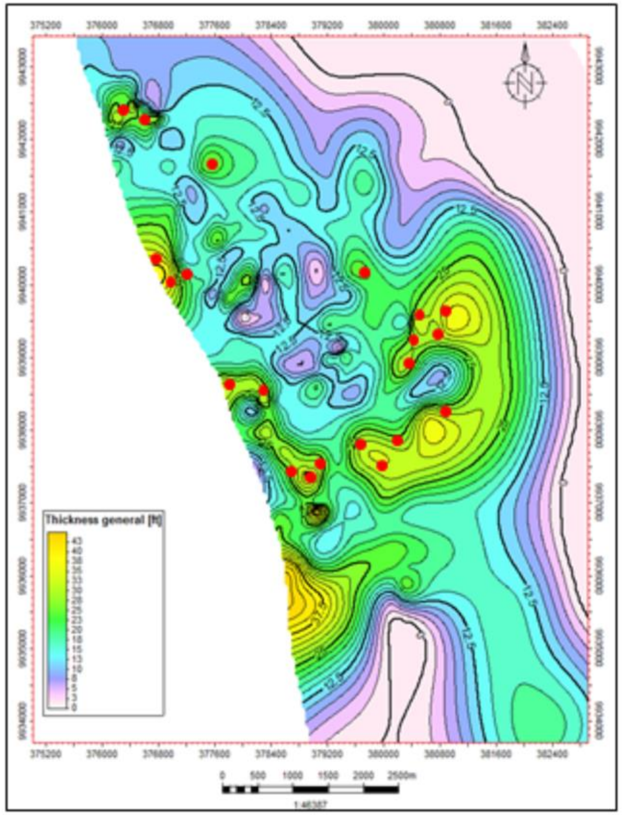
PROJECT DEVELOPMENT – Hydraulic Fractured Wells in M-2





PROJECT DEVELOPMENT – Well Ranking for Workover





Net Pay Map M-2 Reservoir

Presenter's notes : Base on the analysis of reservoir pressure, net pay, productivity index, among others, 21 wells were identify as WO candidates after the analysis of a total of 185 existing wells.
Map to the left Shows in red the location of the WO candidates
Since one of the projects goals was to identify new opportunities WO and New Wells location were analyzed in this slide

Results & Value

- **Results**
  - M-2 new reservoir characterization unveiled excellent reservoir characteristics for those thin beds (Φ=20%, K up to 1.5 Darcy).
    - Glauconite and Calcite are not a primary concern in the best reservoir quality and are present mainly in less saturated low porosity reservoir.
  - A comprehensive multidisciplinary workflow is now available for workover selection and ranking (applicable also to other secondary reservoirs).
  - Improved Hydraulic Fracture Design for M-2
  - This winning strategy for M-2 development was designed and successfully implemented in 4 months.

- **Value**
  - **1,200 Barrels** of incremental oil in 5 wells.
  - For the entire M-2 development strategy the impact will be:
    - **5MM Bls** considered as incremental oil,
    - Workover cost savings and reduction of deferred production for next campaigns
  - Increase the M-2 reservoir reserves from 14 to 19 MMBls as well as its recovery factor to 18%
  - Maximize Eden Yuturi opportunities optimizing water management strategies

Presenter's notes : Since then three wells had been fractured without pre-frac evaluation, post-frac production meeting production prognosis and productivity index range.
Unlocking laminated reservoir full potential, increasing connectivity with fracture.