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Improving productivity in unconventional reservoirs by utilizing petrophysical properties

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Abstract

Understanding permeability in carbonate shales tends to be difficult to predict as the shale presents heterogeneous mineralogy, poorly nano- and micro-pores system, carbonate secondary porosity as dissolution may be also present. Understand fluid types in this reservoir is also critical for effective permeability modelling and consequently design the hydraulic fracturing geometry, injection rate and treatment size, the horizontal spacing optimization and well trajectory design.

In this study, we developed a petrophysical characterization to evaluate optimum zones selection and stimulation design optimization in the Pimienta Formation, Mexico. The petrophysical model included facies model, porosity, water saturation and permeability.

The average values of the petrophysical properties obtained from core samples: φ= 7.3 %, Sw= 55 % VSH: 10.5% ρmat: 2.62 gr/cc, and KPERM= 0.3442 mD are calibrated with the existing petrophysical models at the Medium Pimienta level. The acoustic impedance is low and corresponds to high porosities. The results are indicating that best properties are found in Medium Pimienta towards to the Lower Pimienta Section.

Introduction

Petrophysical characterization of unconventional reservoirs is crucial for the design of complex wells trajectories, multi-fracture stages, to estimate unconventional reserves and then to optimize production. The petrophysical characterization of such reservoirs tends to require more detailed approaches its reservoir formation anisotropy and micro-structure requires traditional and special field and laboratory tests. Identifying best stimulation zones can significantly reduce the field development costs by increasing the efficiency of hydraulic fracturing. This technique is performed to fracture the rock formation, allowing hydrocarbons to move freely to the wellbore for extraction.

The recent development of unconventional plays of oil and gas shales was recently discovered in the Burro-Picachos area, with formations comparable to Eagle Ford, areas in the United States. The unconventional reservoir is also showing to be a potential opportunity to generate hydrogen (Da Silveira et al., 2024), and to form a CO_2 storage after reservoir depletion .

The objective of this study is to propose an integrated methodology to evaluate the Superior Jurassic Pimienta Fm (Salazar et al., 2021). As unconventional resource in Mexico, it is estimated that the size of the gas resource is about: P10 = 171 MMMpcg, P50 = 67 MMMpcg. and P90 = 7 MMMpcg, the probability of geological success (PG) is about 81% to find wet gas.

Methodology and Results

In this study, we developed a petrophysical characterization to evaluate optimum zones selection and stimulation design optimization. The first step comprises the data set evaluation where one open-hole log data, laboratory tests and field measurements were gathered and checked for QC/QA analysis. All data evaluated include total gamma ray, spectral gamma ray, caliper and bit size, neutron porosity, Photoelectric, Bulk density, compressional and shear waves, and resistivity logs. Next, these data were interpreted to formation evaluation, geomechanical model and for production evaluation.

Study location

The Pimienta Formation (Betancourt, et al., 2023 A) is located in the southern portion of the Burgos Basin, Mexico. The same unconventional resources extend to the Tampico-Misantla basin in the South. Figure 1 shows the location of the Well-W, Well-Y and Well-Z wells. Burgos Basin contains reserves of approximately 10.8 MMMBop, whereas southern Tampico Misantla basin contains 34.9 MMMBop.

The Tampico-Misantla Basin in Mexico is recognized for its extensive area and significant hydrocarbon potential, particularly within the Pimienta Formation. Upwards, the Pimienta Formation gradually passes into Lower Tamaulipas Formation. This was originally described as fine-grained, compact limestone with well-marked beddings, predominately gray in color. It concludes many chert lenses and nodules of irregular shape at its top.

Petrophysical Properties

The analysis of the 28 samples at different depths indicated a majority fraction of calcite 59.6%, quartz 14.7% and clays 10.5%. The mineralogy analysis (XRD) indicated 59.6% of carbonates constituted admixture of quartz 14.7%, dolomite 15% and 10.5 % of clay. constituted by illite, and montmorillonite. Also, Master-log indicated ~10% montmorillonite. The main facies are:

Facies 1: Mudstone/Wackestone with radiolarians in silicified parts, increased fractures sealed by calcite, disseminated pyrite, and dolomite. Facies 2: Wackestone/Packstone of Saccocomas recrystallized by calcite, bands of recrystallized calcite, fractures sealed by calcite, and presence of dolomite with fine quartz crystals. Facies 3: Silty Wackestone/Mudstone with recrystallized bioclasts, fractures sealed by calcite, and the presence of fine quartz crystals.

The laboratory petrophysical tests comprises 20 tests of porosity and water saturation. The total porosity average is 4.88%, water saturation average is 13.9%. For laboratory sample #10 the porosity/Sw is 8.1% / 36%, for laboratory sample #11 is 5.1% / 20% and for laboratory sample #12 is 5% / 11.

The results of Vshale indicated values between 3.6% and 11.1%. For laboratory sample #10 the vshale vary from 3.4% to 12.3%, for laboratory sample #11, vshale range from 3.2% to 5.7% and vshale range for laboratory sample #12 from 3.4% to 8.0%.

Fluid Saturation

Archie (1942) equation with m Variable; n=2 has been used for water saturation computation. The results show that water saturation measured from laboratory has an average value of 13.9%. The reservoir profile is indicating water saturation ranging between 32% and 77% for laboratory sample #10, 26% to 86% to laboratory sample #11 and 34% to 70% laboratory sample #12 is 26% to 77%. Permeability was determined by using core samples. The permeameter results indicated that in the reservoir, the values ranged between 1,110 to 2,000 nD (Figure 1).

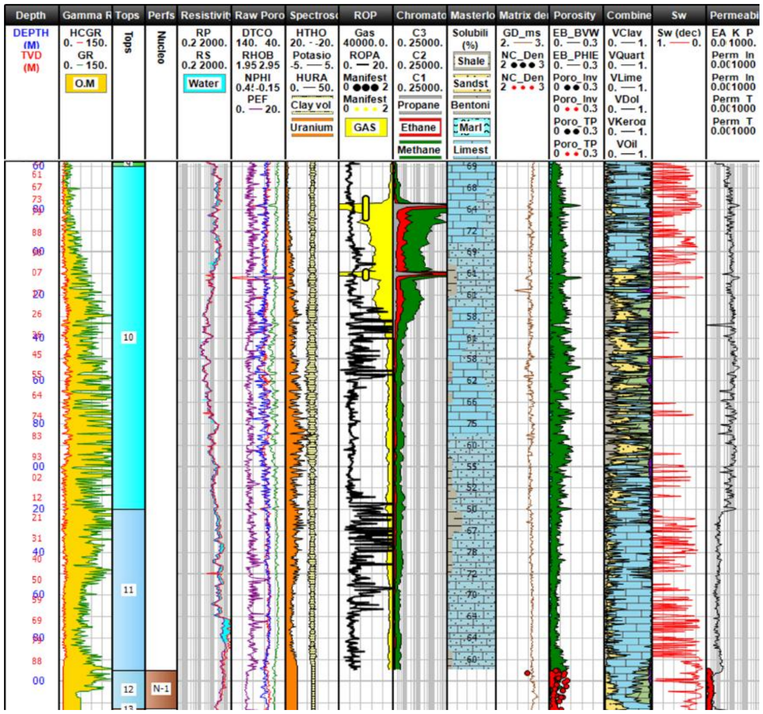

Figure 1. Well-Z – Petrophysical Evaluation

Determination of rock types

The type of rock is determined based on the pore throat radius values and integrating with petrographic analyses, which allows for establishing a permeability-porosity relationship (K/Phi) and irreducible water saturation.

The integration of the Advanced Petrophysics of the Well-W well is shown below in Figure 2, where the correlations using logs were calibrated with laboratory tests from Pimienta Formation. The results are indicating majority of pores are nanoporous (brown color), Microporous (yellow color) and Mesoporous (green color).

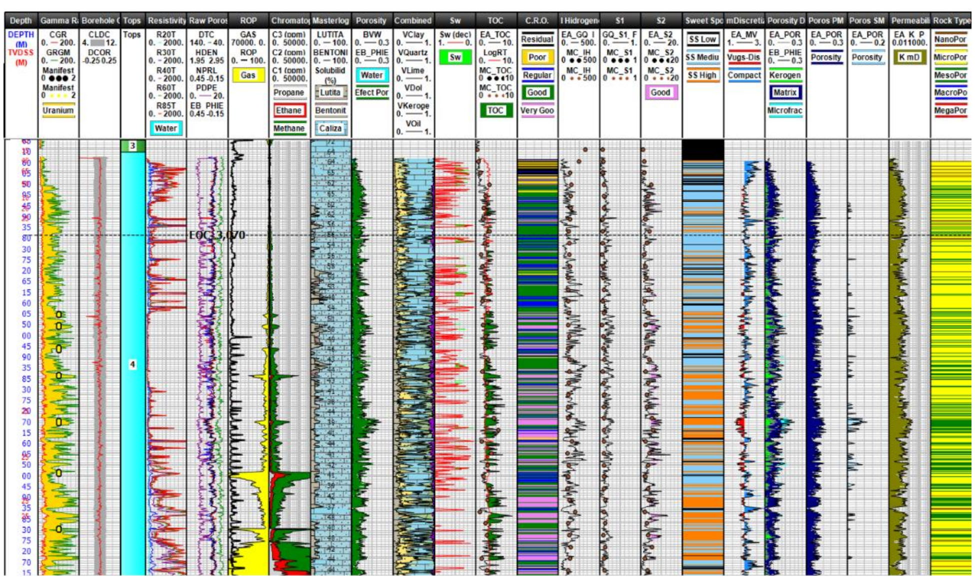

Figure 2. Well-W rock types and facies

Results

There are petrophysical parameters obtained, previous studies carried out, (core analysis, formation water sample: (33,000 ppm - 110,000 ppm), such as the saturation exponent (n:1.8 - 2), tortuosity (a:1), and the resistivity of the formation water (Rw: 0.025), cementation exponent (mV Gómez Rivero equation's) and bottom temperature 118ºC.

The average values of the petrophysical properties obtained from core samples: φ= 7.3 %, Sw= 55 % VSH: 10.5% ρmat: 2.62 gr/cc, and KPERM= 0.3442 mD are calibrated with the existing petrophysical models at the Medium Pimienta level. The acoustic impedance is low and corresponds to high porosities. The results are indicating that best properties are found in Medium Pimienta towards to the Lower Pimienta Section.

Conclusions

The petrophysical characterization and integration of the rock's physics in the study reservoir was effective to identify best intervals for stimulation, but still as it requires the combination with geochemical and geomechanical properties to refine such intervals.

The results indicated an expected TOC of approximately 2.18%, type II, with a thermal maturity ranging between 0.85 and 1.1%. The mineralogy analysis indicated that mudstone, wackestone and packstone contained 59.6% of the carbonate, quartz 14.7%, dolomite 15%, and 10.5% of clay including illite, montmorillonite, glauconite and kaolinite. Permeability in the reservoir ranged between 0.0812 to 1.3464 mD, with total porosity ranging between 4 and 11%. The results shows that the best interval for stimulation was in the calcareous limestone facies in the middle to the bottom intervals.

References

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