
**Submission code: 0BQAPW4DBQ**

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# Using geomechanics for optimizing productivity in shale oil reservoir

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## Abstract Summary

This study presents an integrated characterization to evaluate the geomechanical properties of the carbonate oil shale of the Pimienta formation, a Tithonian Superior Jurassic Reservoir. To build the geomechanical model for optimizing stimulation design for increasing productivity an extensive laboratory tests used to calibrate geomechanical properties used using geophysical logs to characterize the reservoir, define the sweet spot zones and validate with production logs. The reservoir characterization included mineralogy analysis, elastic properties and brittleness estimation using elastic properties. The rock physics and geomechanical analysis were designed to obtain the elastic properties (Poisson's Ratio, Young's Modulus), obtain the acoustic impedance and to estimate brittleness. The analysis compared well production with lithofacies and rock properties to identify the best potential intervals and zones for improve the production efficiency.

The results shows that the reservoir present average reservoir pressure of 8,200 psi. The geomechanical model results indicated a median Young's Modulus of 5.42 (10^6 psia), a static Poisson's Ratio of 0.27, an acoustic impedance of 42,785 ft/seg*gr/cc), with an excellent brittleness around 61% in the best stimulation intervals. The UCS is ranging between 12,404 psi to 17,603 psi in the sweet spot zone for stimulation in the carbonate shale formation. The combined geomechanical analysis show that the best interval for stimulation was in the carbonate shale that presents high brittleness, good reservoir quality located in the zone stimulation zone #10 at depths ranging between 8,727ft to 9,251ft. This study also presents the used strategy to identify the sweet spot zone and how it was used to optimize the hydraulic fracturing design in the selected zone.

## Introduction

Geomechanics is a key discipline traditionally used for wellbore stability optimization (optimum mud weight and casing depth), sand production prediction (optimum drawdown strategy and sand exclusion strategy (when applicable). Most recently geomechanics shows to be extremality valuable discipline for increase productivity in shale oil reservoirs.

Currently, shallow and light-oil reservoirs can be difficult to find out in Mexico. For this reason, oil and gas operators are exploring and developing complex, risky and therefore costly reservoirs such as unconventional plays of oil and gas shale. This is the case of the Pimienta Formation, located in the southern portion of the Burgos basin in Mexico, which has been identified as a good potential source rock to become a shale oil producer.

The objective of this study is to propose a integrated methodology to evaluate the Superior Jurassic Pimienta fm (;; Salazar et al., 2021; Betancourt et al, 2023). 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.

## Method and/or Theory

### *Study location*

The Pimienta formation is in the southern portion of the Burgos Basin, Mexico (Betancourt et al., 2023). The same unconventional resources extend to the Tampico-Misantla basin. Burgos Basin present reserves of approximately 10.8 MMMbcpce and, with substantial reserves. In the south region of Mexico exists another important basin, called Tampico Misantla with 34.9 MMMbpce. The stratigraphic column of Pimienta fm. consists of the Lower Oligocene, which is made up of calcareous light gray shale, the Lower Eocene is constituted by light, gray, calcareous shales, in which at the bottom of formation traces of light gray sandstones, with fine to medium quartz grains and dark lithics been identified.

*Geomechanic and rock physics characterization: Elastic parameters*

The laboratory campaign included ultrasonic measurements, mechanical (triaxial tests) and density. The ultrasonic tests comprise the measured P-wave (VP) and S-wave (VS) velocities using two (2) samples and bulk density tests were executed with 2 samples. The triaxial tests also comprised 6 tests. The tests were executed on member #10 (Lower of the reservoir fm.). The density data was also integrated with density log. Vp, Vs and density were used to calculate the Dynamic Young's modulus (Edyn in MPa) using the following relationship.

The dynamic Young's modulus and Poisson's ratio values were higher than the static values as expected. The acoustic tests indicated that the average compresional velocity is 16,530 ft/sec; shear velocity is 9,215 m/s. Dynamic Young Modulus estimated in the lab. Was about 5.42 (10^6 psia) and the dynamic Poisson Ratio was about 0.27.

Static Young's Modulus and Poisson's ratio reach out average values about 5.42 (10^6 psia) (SD=0.45) and Poisson ratio about 0.27 (SD 0.01). The linear relationship between static and dynamic parameters was approximately 0.51 for Young's modulus and 0.71 for Poisson's ratio (Fig. 2). The young modulus for For member #10 from 5.85 to 9.13 (10^6 psia), for member #11 from 6.98 to 9.16 (10^6 psia) and for member #12 from 6.84 to 7.65. (10^6 psia) The Poisson ratio for member #10 range from 0.22 to 0.32, for member #11 from 0.26 to 0.33 and for member #12 from 0.26 to 0.30. Density ranges from 2.52 to 2.63 for For member #10 from 2.58 to 2.64, for member #11, and from 2.59 to 2.65 and for member #12.

The UCS of intact rock is among the main parameters used in almost all geomechanical projects. The results of UCS are ranging between 12,404 psi to 17,603 psi in the sweet spot zone for stimulation in the carbonate shale formation. The mineral composition of the rock is usually obtained from laboratory analysis of rock samples using 28 samples X-ray diffraction analysis indicates that calcareous rock is the predominant component in the analyzed samples. The study formation compress of calcite constitutes 84.22% of the rock composition. Siliceous constituents, which include quartz, feldspar, and plagioclase, represent 8.54% of the sample. Clay minerals account for 4.53%, while dolomite comprises 0.60%.

Brittleness using elastic parameters is discretized in the color palette shown in Figure 3. The dividing lines are drawn, considering that the points in the upper left quadrant are the most fragile (blue) and those in the bottom right are the least fragile (red-orange). Low Poisson ratio, high Young's modulus values were found in the sweet spot zone, which indicates high average brittleness equal or higher than 61%. (Figure 1).

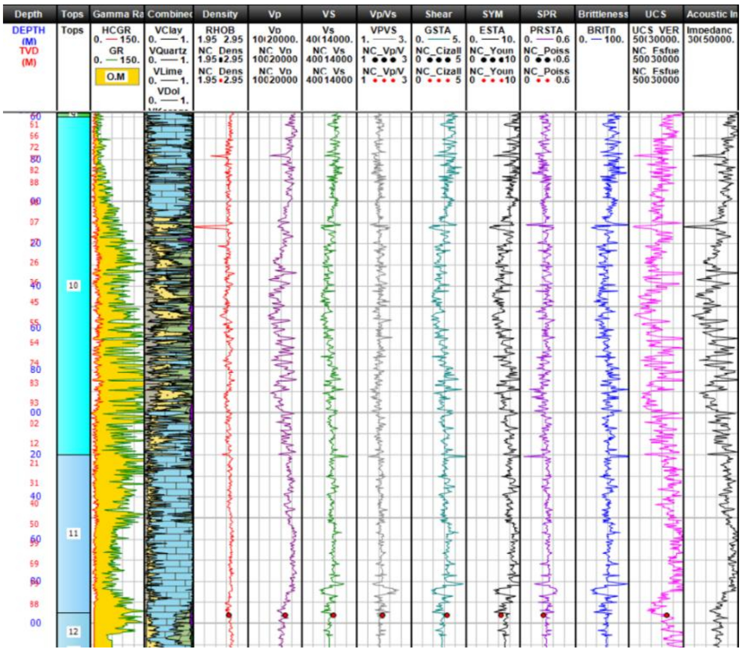

**Figure 1.** Tracks from left to right are: vertical profiles of top of members, GR, Multimineral , density, Vp, Vs, Vp/Vs, Shear modulus, Static Young's modulus (SYM), Static Poisson's Ratio (SPR), Brittleness, UCS, and Acoustic Impedance.

*Geomechanics, hydraulic fracturing and production analysis*

This study presents an integrated characterization to evaluate the productivity potential of light oil in the carbonate shale of the Pimienta formation, Tithonian Superior Jurassic. The well was drilled horizontally in the reservoir for 4,937 ft with 10 stages proposals of completion. To develop the proposed study, extensive laboratory tests, logs, and field measurements were used to characterize the reservoir and to define the appropriated hydraulic fracturing design. The rock physics and geomechanical analysis included elastic properties, UCS, brittleness to define the sweet spot interval. The analysis compared the sweet spot areas with real well production in each stimulation interval, validating the best flow intervals. The study well was completed with 4 ½" external diameter and the hydraulic fracturing will execute in 10 stages, in a horizontal section. The Modified Lorenz Stratigraphic graph of x,x00 - x,x25 md was generated, to identify which units contribute and validate with the evaluation petrophysics (Figure 2).

**Results**

Based on the properties of the rock, Young's Modulus, Poisson's ratio, UCS, brittleness, porosities and permeabilities, it's clear to see that not all stages present good geomechanical properties for high stimulation and reservoir quality. Permeabilities are less than 0.0001mD in such intervals. Given the Flow Unit calculations, the %KH fluid contribution and storage is very low, considering these properties in these intervals, the use of hydraulic fracturing was not efficient or even necessary. Well W exhibits an average Britt Fragility of 61%.

A critical aspect of this methodology is the assessment of synthetic PLT (PLT Syn). This requires the identification of flow units and the validation of both storage capacity and flow dynamics through a cross plot comparing Porosity (PHIE) and Permeability (K). The results show that is evident that the optimal petrophysical conditions and properties are predominantly located within the intermediate zone. This zone contributes approximately 85% to production, while the remaining 15% is attributed to FU-1, FU-16, and FU-17.

## Conclusions

The calculation of elastic properties of the rock showed to be a good calibration with the laboratory results. Low Poisson's ratio, high Young's modulus, which indicates a high degree of brittleness of 61% were indicating great intervals for stimulation. The acoustic impedance is low and corresponds to high porosities, which means that zones are good for stimulation.

Direct production measurement in each stage shows to be a key strategical solution to validate the efficiency of the geomechanical model, validating the importance of estimating brittleness to define sweet spot areas for stimulation. The production data validated the importance of geomechanical model, where high stiffness, high brittleness, high UCS show to be critical for selecting stimulation zones.

## References

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