FEASIBILITY STUDY OF SQS ATTRIBUTE APPLICATION FOR POROSITY ESTIMATION IN CARBONATE RESERVOIR, CENTRAL LUCONIA

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ABSTRACT

This study shows the reliability of an improved attribute or elastic properties, namely SQs and SQp to estimate porosity in a carbonate reservoir. Both SQp and SQs attributes are reliable to predict porosity in a carbonate reservoir. However, SQs shows a better correlation (0.96662). Thus it was selected as an input to calculate empirical equation which, was later used to create a porosity model. The model was compared with actual porosity from the real well data, which yielded a high correlation of 0.961911. Thus, SQs is highly reliable to estimate the porosity in the carbonate reservoir through the empirical equation.

Keywords: Elastic properties, Porosity, SQp and SQs, Central Luconia

INTRODUCTION

Predicting reservoir characteristics such as porosity in carbonates rocks can be difficult due to the complex pore system of carbonates than siliciclastics. It is mainly due to the biological origin of carbonate sediment and its chemical reactivity. Besides, the wide variety of grain shapes that commonly found in carbonates make it even more complicated. In addition, the presence of intragranular, framework, fenestral carbonate porosity, and the potential for the development of moldic and irregular dissolution, related carbonate porosity, also contributes to the complex pore system in carbonate rocks [1].

Gamma-ray and resistivity are important reservoir properties. Gamma-ray log used to distinguish the sandstone and the shale. Thus, it is using to predict lithology. Resistivity logs, on the other hand, give information about the fluid content of the reservoir. Up until now, it is hard to acquire the ideal pseudo logs of gamma-ray and resistivity from elastic properties that can be obtained from seismic data.

Nevertheless, various endeavours have been proposed to inexact the qualities of lithology and fluid indicators. By performing a rotation technique into certain angles, one can approximate the resistivity log and gamma-ray log. This method is known as Amplitude Versus Offset (AVO) rotation technique under AVO technology.

Timko [2], connected the seismic rotation technology to deliver a pseudo-gamma-ray log to tackle the issue of sand/shale interbedding in the Lower Cretaceous of Near Base Cretaceous (NBC). The forecast for resistivity from flexible properties has likewise been rehearsed. Xu and Duta [3], utilized both P and S waves to foresee resistivity, which obtained from seismic inversion result. Mavko et al. [4], who utilized a model of plane-wave spread in the viscoelastic medium, as administered by the Kramers– Kronig connection. By utilizing the Hudson Crack Theory, the inverse Quality factor of the P and S waves (Qp and Qs) were characterized as far as bulk and shear modulus. SQp and SQs qualities created to rationalize the reliance of the condition on the constriction parameter. According to Hermana et al. [5], the SQp and SQs are formulated, as in:

$$SQp = \frac{51(M/G - 2)^2}{6\rho (M/G - 1)}$$

$$SQs = \frac{101(M/G)}{3\rho (3M/G - 2)} \qquad (1)$$

where M/G is the ratio of bulk and shear modulus that can be approximated from the P-wave and S-wave velocity ratio.

Generally, the porosity can be predicted directly if we can retrieve the entire undamaged core from the reservoir. X-ray computerized tomography scans, thin sections, and scanning electron microscope examination used to determine the porosity in the cores. Unfortunately, in many cases, geoscientists failed to retrieve undamaged cores from the reservoir. Thus, indirect prediction methods are widely being used in the industry to estimate porosity outside of the well. This study shows, the feasibility of SQs and SQp attributes to estimate porosity. This research aims to study the feasibility of SQs attributes to predict porosity in carbonate reservoir of Field X in Central Luconia, Malaysia.

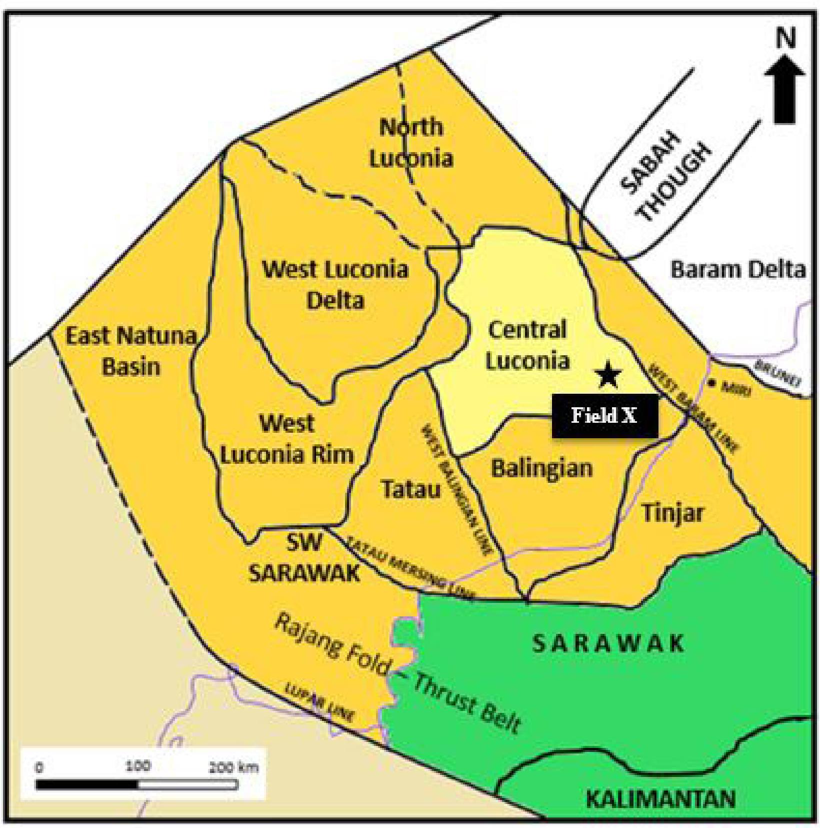

Figure 1 Location map of the Field X of Central Luconia, Malaysia (Modified from Madon [6])

METHODOLOGY

There are a few steps involved in the research workflow to meet the expected results. The research workflow was carried out using HampsonRussell and PETREL software. The steps of the research workflow, as shown in Figure 2.

analysis carried out to identify the zone of interest, in our case, it was the top of carbonate, the base of carbonate and the gas-water contact (GWC).

The next step after the well log data analysis is the elastic properties calculation. Understanding the performance of elastic properties to get the best

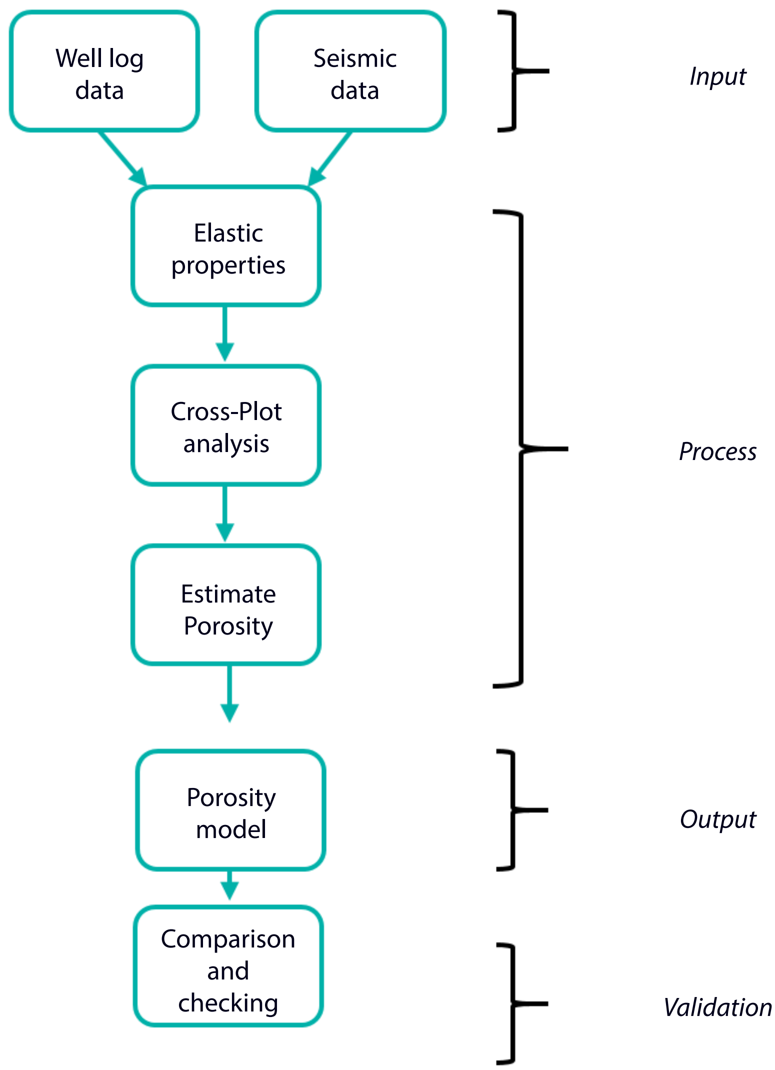

Figure 2 Research work flow of the project

The well log data of two carbonate reservoirs of X Field in Central Luconia, Malaysia, was loaded into HampsonRussell software. Upon receiving, the well log data undergo a quality check and data conditioning. Data conditioning will eliminate any values in the data set, which could be detrimental to train the neural network. Besides, the well log data estimation on porosity is vital to minimalize the drawbacks in the interpretation. The elastic properties such as P-impedance (AI), S-impedance (SI), Lambda Mu Rho (LMR), SQp and SQs attribute were calculated from Vp, Vs and density data of Well S-1 and S-105 using HampsonRussell software.

Table 1 Summary of well log data for Well S-1 and S-105

Log / Well	Gamma ray	Density	P-wave Velocity	S-wave Velocity	Vp/Vs ratio	Neutron-Porosity	Resistivity	Porosity
S-1	X	X	X			X		X
S-105	X	X	X	X	X	X	X	X

Table 2 Summary of Top of carbonate and zone of interest

Well Name	Top of carbonate, (ftss)	Zone of interest, TVD (ft)
S-1	9263	9340 - 10150
S-105	9398	10449 – 11596.5

Mathematically the elastic properties are formulated as:

Table 3 Formula used to calculate elastic properties

Elastic properties	Formula
P-impedance (AI)	$AI = Vp \times \rho$
S-impedance (SI)	$SI = Vs \times \rho$
Lambda Mu Rho (LMR)	Lambda-Rho = $\lambda\rho = Zp^2 - cZs^2$ where $2.0 \le c \le 2.5$ Mu-Rho = $\mu\rho = Zs^2$
SQp	SQp = (5/6) *(1/Rho) *(((a-2) ^2)/(a-1)) $a \approx Vp/Vs$
SQs	SQs = (10/3) *(1/Rho) *((a)/((3*a)-2)) $a \approx Vp/Vs$

The following step is to create the cross-plots. The analysis is incorporated in the cross-plots using the generated elastic properties. From this cross-plots, the author was able to verify whether a particular elastic property can be a good indicator of porosity or not. Later, an empirical equation of the selected elastic property was used to predict porosity. By calibrating the well log data interpretation to the seismic data interpretation, a relationship where a porosity model can be created between the wells.

To apply the SQp and SQs attributes in real seismic data, a data set consists of near and far seismic stacks and well data are used as input for the simultaneous inversion to acquire the basic elastic impedance of P-imp, S-imp, and density. The porosity model from SQs attributes was then calculated from the inversion result using Equation (2). Lastly, the predicted porosity from the empirical equation compared with the actual porosity from well data to validate the accuracy and reliability.

RESULTS

Cross-plot analysis

The cross-plots were created between porosity versus elastic properties. The main aim to create these cross-plots is to check the efficiency of certain elastic property as a parameter to estimate porosity in a carbonate reservoir. The colour-coding was assign based on porosity attribute to visualize better. The results are as per below.

The SQs and SQp attributes tested to check the reliability to predict porosity in carbonates. Figures 3 and 4 show the cross-plot between the porosity with SQs and SQp attribute, respectively. From the cross-plots, a trend of linear relation was observed in both attributes. Porosity and SQs produced a good correlation of 0.96662. Thus, this elastic property can be used as an input to calculate the empirical equation to estimate porosity.

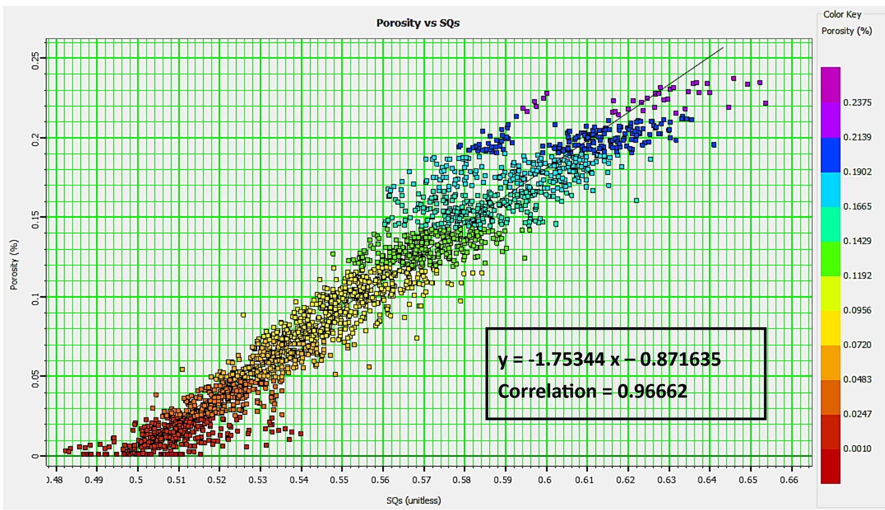

Figure 3 Cross-plot of Porosity vs SQs

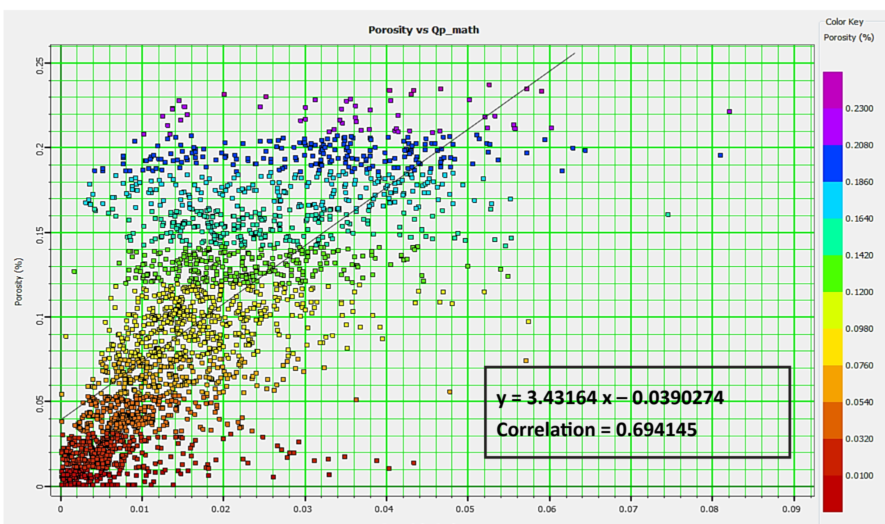

Figure 4 Cross-plot of Porosity vs SQp

On the other hand, a weak correlation of 0.694145 was established in SQp. Hence, this elastic property is not recommended to be used as an input to create a porosity model through empirical equation even though it can distinguish porosity into a higher and lower value. The cross-plot analysis also conducted with other elastic properties such as P-impedance, S-impedance, Mu-Rho, Lambda Rho and Density. An inverse correlation was observed with a similar distinctive trend.

The relationship between two variables can change over time and may show periods of positive correlation as well. However, in this study, the author aims to explore the visibility of trends or correlations between the elastic parameters with porosity. In the figure shown below, a well-correlated result is observed hence proving that a good relationship is established between each elastic property and porosity.

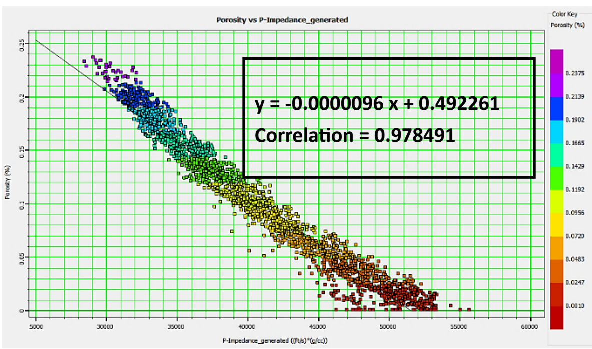

Figure 5 Cross-plot of Porosity vs P-imp

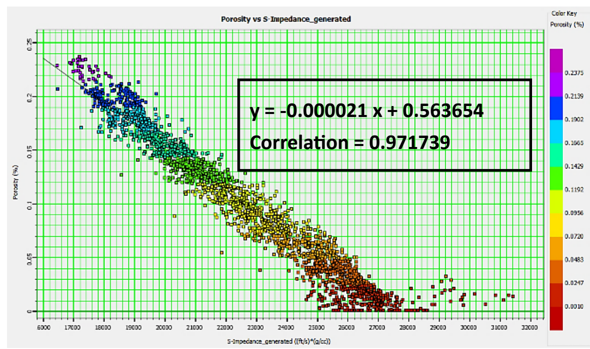

Figure 6 Cross-plot of Porosity vs S-imp

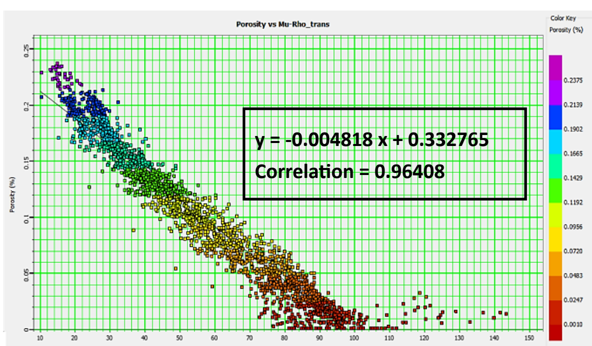

Figure 7 Cross-plot of Porosity vs Mu-Rho

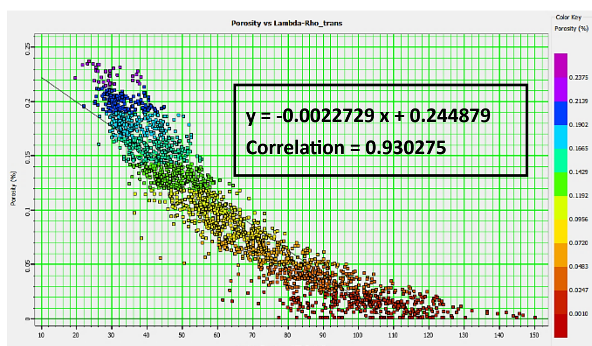

Figure 8 Cross-plot of Porosity vs Lambda-Rho

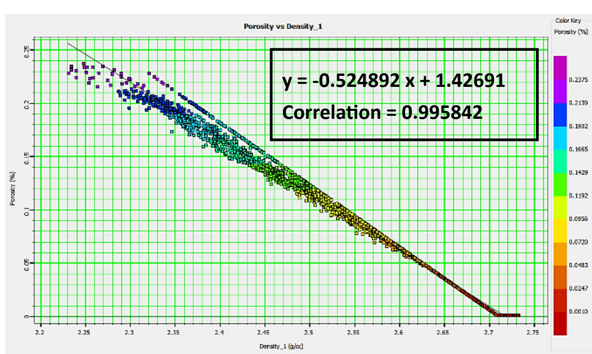

Figure 9 Cross-plot of Porosity vs Density

Predicted Porosity from Empirical Equation

SQs was selected as an input to estimate porosity from the empirical equation. This is because the SQs yielded a good correlation of 0.96662 with porosity. The equation used was as below:

$$y = -1.75344x - 0.871635 \quad (2)$$

where the original SQs equation substituted *x*, refer to Table 3.

A porosity model was created through the empirical equation of SQs porosity (Figure 10). The predicted porosity from the empirical equation of SQs yielded a excellent correlation of 0.961911 with the actual porosity from well data (Figure 11). It provided a better and more precise indication of porosity in the carbonate body. A higher amplitude can be noticed on the top of carbonate till gas-water contact and lower amplitude can be seen in the water zone. The higher porosity is observed at the gas zone, which

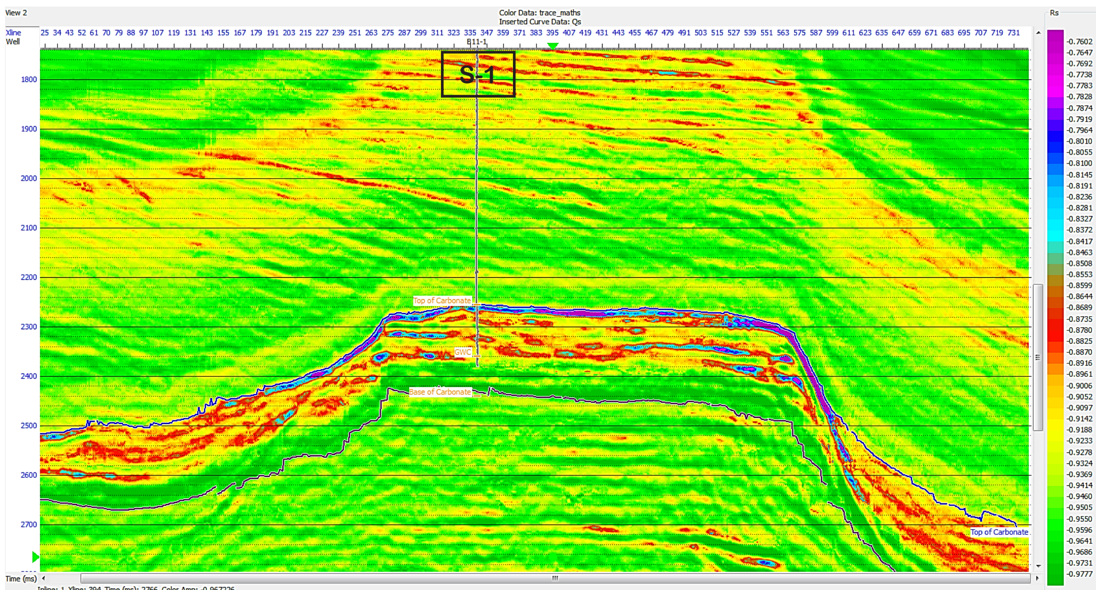

Figure 10 Porosity model from Qs porosity empirical equation

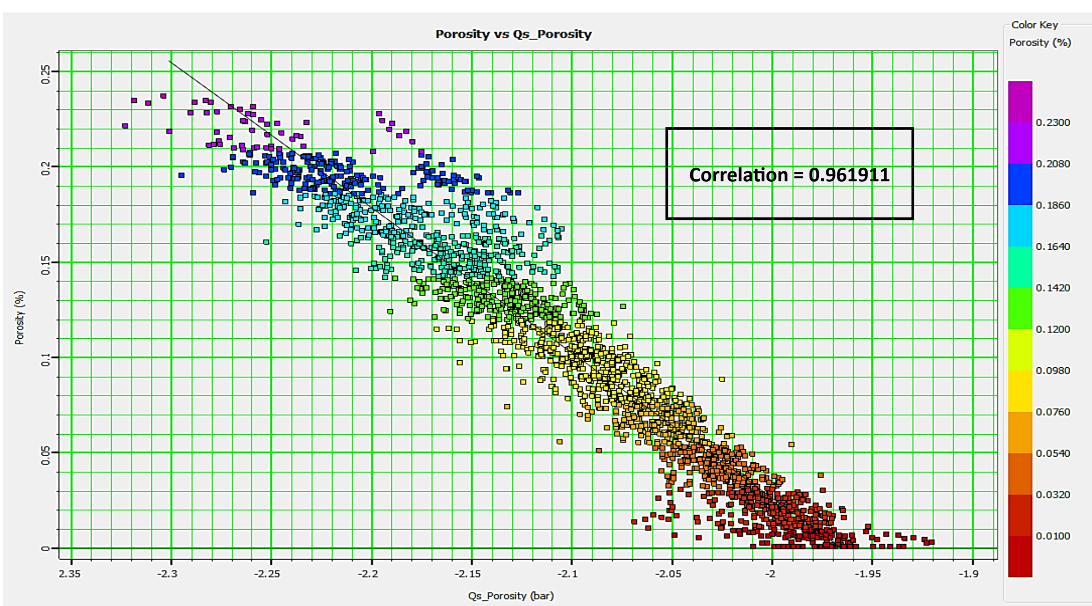

Figure 11 Cross-plot of Porosity vs Qs Porosity

matches with the well log data (Figure 10). Thus, SQs attribute is highly reliable to predict porosity in carbonate body.

CONCLUSIONS

The methodology adopted had been able to meet the objectives of this project successfully. This project mainly focuses on the application of new elastic properties, namely SQp and SQs to estimate the porosity and its reliability in a carbonate reservoir. Based on the results, it can be concluded that both SQp and SQs is unfailing to predict porosity in carbonate reservoir as it shows a good trend in distinguishing the higher and lower porosity values. However, SQs was selected as an input for the empirical equation to create a porosity model. This is because SQs shows a better correlation of 0.96662 than SQp. A porosity model was created in this project from the empirical equation of SQs and the predicted porosity from the model was compared with actual porosity from the well data to check its accuracy and reliability. From the comparison, the porosity estimated from empirical equation yielded a better correlation of 0.961911. In conclusion, SQs is highly reliable to estimate the porosity in carbonate reservoir through the empirical equation.

FURTHER STUDY

As for the further study, the author suggests conducting this research on other carbonate reservoirs to test the reliability of the SQs and SQp on estimating porosity. Overall, it is also recommended for the expansion and continuation of this project. This is mainly to determine the other petrophysical properties such as permeability and water saturation to validate the estimation performance further using SQs and SQp attributes in a carbonate reservoir.

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