Increasing hydrocarbon prospect zone using deterministic model based on logs and core data in “X” field

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Abstract. X Field was developed by drilling 3 oil wells, X-1, X-2, and X-4 to determine the hydrocarbon prospect zones. Therefore, this study aims to analyse and identify the prospect zones in each well to obtain petrophysical values. This helps to predict the interval zone for hydrocarbon prospects. The study analyses the log and core data using deterministic methods. The rock characteristics that need to be determined include shale volume, porosity, water resistivity, and saturation, and oil column thickness. The thickness of the layer as a prospect reservoir is determined using the gamma-ray log based on the volume of the shale. The porosity size is carried out using density and neutron logs. Additionally, the available resistivity log data is used to calculate water saturation through the Archie method. The average porosity and water saturation in the “X” field was 16% and 66%, respectively. Also, the cut-off is carried out with limits on shale volume, porosity, and saturation of 17%, 8%, and 66%, respectively. The final result in the form of reservoir lumping includes the average value of net pay, porosity, and water saturation of 56 ft, 21%, and 38%, respectively.

1. Introduction

The “X” field has productive layers dominated by limestone. Evaluation of its formation is carried out to determine the prospect layers containing hydrocarbons and their depth based on the physical properties of the rock. This study uses log and core data, which is commonly employed in case the core samples are sufficiently available [1]. The result shows that the quality of the data produced is very accurate compared to other empirical formulas. In this article, the physical properties of rocks that needs to be determined include shale volume, effective porosity, water resistivity, and saturation, and thickness of oil column of prospect zone. There is a need to study log analysis and formation evaluation on the prospect layers in the "X" Field to identify the physical properties of rocks and determine the location of the prospect zone's depth.

2. Methods

Before log analysis, complete data preparation is needed for interpretation to be appropriate [2]. The more complete the data, the better the interpretation. The data available include log headers, depth of each well, LAS, routine, and SCAL, which are further used to determine the value of the physical properties of rocks, including shale volume, effective porosity, water resistivity, water saturation, and thickness of the oil column from the prospect zone. The stages are shown in figure 1.
3. Results and discussion
The data collected is Quicklook Interpretation and Analysis of Calculation, each for a specific reason. For instance, qualitative analysis helps in the estimation of the position and location of zone depths, indicated as prospect intervals. Afterward, calculation analysis is carried out to determine the value of rock petrophysics.

3.1. Quicklook interpretation
Quicklook Interpretation is conducted by displaying log data on standard triple combo layout. The parameters used to mark prospect intervals include the low of gamma-ray log curves, the height of resistivity curves, and the low of neutron and density curves. Figure 2 shows an example of a triple combo from well X-4.

![Diagram of Research Flowchart](image)

**Figure 1.** Research flowchart.

![Triple Combo of Prospect Interval for Well X-4](image)

**Figure 2.** Triple combo of prospect interval for well X-4.
Based on figure 2, it can be seen that the prospect zone of the X-4 well is at a depth of 4942 ft - 5111 ft. using the same method, the depth of prospect zones in wells X-1 and X-2 can be determined respectively are estimated to be at a depth of 4790 ft-5007.5 ft and 4741.25 ft-5007.5 ft.

3.2. The analysis of calculation

The Analysis of Calculation is preceded by the determination of the value of a, m, and n for tortuosity, cementation factor, and saturation exponent, respectively [3-7]. It is carried out using the analysis of SCAL and the determination of m is based on the slope of the formation factor log and porosity log plots [8]. Also, a is obtained from the intercept when porosity = 1. The determination of m is shown in figure 3. Since the value of the plot slope is -1.95, m is 1.95.

![Figure 3. Determination of the cementation factor.](image)

The determination of the saturation exponent value is based on the slope of the brine saturation log plot from core analysis and the resistivity index, as shown in figure 4. Since the value of the slope is -1.99, n was 1.99.

![Figure 4. Determination of saturation exponents.](image)

After a, m, and n values are established, the determination of the formation water resistivity value is carried out using resistivity of NaCl water solutions chart [9,10]. Measurements are made using formation water samples from the prospect zone measured at room temperature. NaCl concentration in formation water samples was 14000 ppm. Based on the chart, then it is obtained the formation of water resistivity value at room temperature is 0.45 ohm. Then, the resistivity value of water at the formation temperature is obtained using the following formula.
\[ R_2 = R_1 \times \left[ \frac{(T_1 + 6.77)}{(T_2 + 6.77)} \right] \]

Water resistivity value was 0.175 ohms at the formation temperature of 180°F is obtained after conversion is performed.

The shale volume analysis was performed based on gamma-ray parameters, and the results are shown in figure 5. Based on the analysis, the average value of shale volume in wells X-1, X-2, and X-4 was 9.89%, 9.47%, and 12.10%, respectively. Based on the shale volume values obtained, it is estimated that wells X-1, X-2, and X-4 have clean formations.

Porosity analysis was based on neutron-density [11], and the results are shown in figure 6. This method uses the values of neutron wet clay, rho wet clay, and rho dry clay to be used to calculate porosity. Determination of wet clay for neutrons and densities is determined based on the average value of neutrons and densities in the pure shale zone. Then the neutron wet clay value = 0.498 and rho wet clay = 2.374 are obtained. Whereas the determination of dry shale is based on the type of mineral shale. The mineral shale contained is kaolinite. Then we get the value of rho dry clay = 2.69. Based on the analysis, the average porosity values in wells X-1, X-2, and X-4 were 17.88%, 14.58% and 15.75%, respectively. With the porosity values obtained, the porosity in wells X-1, X-2, and X-4 can be classified as good porosity.

The determination of formation water saturation in well X using the Archie method was conducted [1,12]. This approach was chosen because the formation at the prospect interval is relatively clean as shown in Figure 5. The result of water saturation determination using Archie method shown in figure 7. Based on figure 7, the saturation value of formation water in wells X-1, X-2, and X-4 is 47%, 60%, and 64%, respectively.
Figure 7. Formation water saturation analysis using the Archie method on wells X-1 (red), X-2 (yellow), and X-4 (green).

3.3. Cutoff
There are 3 parameter values that need to be determined, including volume, porosity, and water saturation [13,14]. The determination of the cutoff limit of shale volume and porosity in the field is carried out using a statistical approach due to the lack of detailed well test data. The cutoff limits of clay volume, porosity, and water saturation were 17%, 8%, and 66%, respectively. Based on the predetermined limit, the lumping reservoir of wells X-1, X-2, and X-4 are shown in table 1.

Table 1. Reservoir summary.

| WELL | RESERVOIR SUMMARY | PAY SUMMARY |
|------|-------------------|-------------|
|      | GROSS (FT)        | NET RES. (FT) | NTG | VCLAY (dec) | POR (dec) | NET PAY (FT) | NTG | VCLAY (dec) | POR (dec) | SW (dec) |
| X-1  | 217.5             | 163.50      | 0.75 | 0.05        | 0.20      | 98.5        | 0.45 | 0.03        | 0.20      | 0.36     |
| X-2  | 253.25            | 97.63       | 0.39 | 0.04        | 0.19      | 73.6        | 0.29 | 0.03        | 0.22      | 0.43     |
| X-4  | 169               | 89.50       | 0.53 | 0.09        | 0.21      | 66          | 0.39 | 0.08        | 0.25      | 0.56     |

4. Conclusions and suggestions
Based on the results of data analysis and calculations, wells X-1, X-2, and X-4 have the potential to be developed since they have sufficient physical properties of rock. For further research, the estimation of the petrophysical value of rocks needs more accurate data. This study produces values of shale content, porosity, water saturation, and thickness of the oil column from the prospect zone, which can be used as the basis for further studies.

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