Reservoir characterization by petrophysical analysis and core data validation, a case study of the “x” field prospect zone

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Abstract. Petrophysical analysis has been performed by evaluating log data that have been validated with core data using Geoframe 4.2 software. Using secondary log and core data which are located at depth of 1414 - 3820 ft, the research purpose is identifying reservoir characteristics of "X" field prospect zone. Sand A-Zone has permeability of 9.38% error curve and porosity curve error of 0.78%. In Sand B Zone permeability error of 52.32% curve and porosity error of 7.13%. In Sand C Zone permeability error of 198.8% curve and porosity error of 2.85%. In Sand D Zone permeability error of 61.54% curve and porosity error of 29.87%. In Sand E Zone permeability error of 54.73% curve and porosity error of 4.52%. There is no good correlation and error values that tend to be large because the lithology in Sand B and Sand C Zone has a tight range of lithology, so the reading of logging tool gives a fairly high error, especially in permeability data which still shows a decrease in error value after validated with core data. Quantitative analysis obtained by petrophysical parameter range from six zones porosity of 26 %, permeability of 2661 mD, and water saturation of 0.37 frac.

1. Introduction
The process of carrying out petrophysical analysis produces data that are very necessary for the identification and manufacture of reservoir models and estimation of hydrocarbon reserves. The resulting data is a petrophysical analysis of logging interpretation; interpretation is done by reading and comparing logging response. In this study, the determination of porosity, permeability and water saturation will be carried out [1]. After that, log data analysis was performed using the results data from well logging in the form of recording physical parameters of the depth which aims to obtain petrophysical parameters [2]. To obtain a valid analysis result, the results of the hydrocarbon zone analysis using log data are validated with core data using RCAL (core analysis laboratory routine) [3].

Cores can also be called core samples are parts of material or substances taken from the wellbore. Core samples are the most trusted source of information because they directly take samples on drilled well rock. This causes the wells which are carried out by core data analysis to become reference wells as quality control from the results of interpretation and petrophysical calculations for other wells to be drilled around the reference drill. Core data itself is data generated from sample core analyzed in the laboratory in the form of physical parameters of rock [3]. Interpretation is done with log data and core data to obtain the physical parameters of the formation needed so that it can be ascertained the exact range of petrophysical parameters such as permeability, porosity, water saturation, reservoir zone spread and the making of ELAN models from the interpretations made. ELAN stands for Elementary
Analysis which is part of Geoframe 4.2 software made by Schlumberger. ELAN itself is a probabilistic program with reverse solutions (inversion). This research refers to previous studies. In another study previously carried out petrophysical analysis and made the ELAN model but did not use core data as validation [4]. With the same purpose, other studies previously calculated the petrophysical parameters validated with core data and showed the value equation between log data and core data but did not create the ELAN model [5]. In another study, petrophysical analysis was carried out with log data and core data and made 2D and 3D modeling based on net-pay values but did not make the ELAN model [6]. In this research, a petrophysical analysis will be conducted with validated log data using core data, and after that an ELAN model is created from the results of the interpretation carried out by petrophysical analysis with validated log data using core data using RCAL analysis (core analysis laboratory routine) and after that the ELAN model of the results of the interpretation carried out.

The location of the research data collection was conducted at Well 01 X at Field X which was located in the area of South East Sumatra (SES). The Southeast Sumatra Block is located at 04 ° 30 ' - 06 ° 00 ' LS and 106 ° 00 ' BT - 107 ° 00 ' BT. This block is part of the North West Java Basin. In this area is divided into 3 blocks, namely North, Central and South and is divided into 2 basins, namely Asri Basin which is located in the North Block and Sunda Basin which is located in the Central and South Blocks. Location of research data collection was carried out in the North Asri Basin Block.

2. Research methods
As shown in Figure 1. there are two analyzes used in this study namely qualitative analysis and quantitative analysis. Qualitative analysis is an analysis of log data that has been made into a well composite log and then interpreted in a quick look based on the shape of the log curve deflection to determine the lithology of the formation in well x so that the prospective hydrocarbon zone distribution can be known. Quantitative analysis in the form of evaluation of log data carried out simultaneously by the response equation determined from interpretation models using software.

The software used in this study include Microsoft Office (Excel) and Geoframe 4.2. As seen in the flow chart in Figure 1, the first step is to input log data, then perform the well composite phase, namely the display of log curves that are used for qualitative interpretation in lithological analysis in a quick look or quickly. After the lithology interpretation is carried out, the determination of hydrocarbon zones is based on the results of previous lithological interpretation. After the division of the hydrocarbon zone is then entered into the ELANplus stage, which is one part of the Geoframe 4.2 software that functions to evaluate log data that is carried out simultaneously with the response equation of the interpretation models.

2.1. Data input
2.1.1 Data input software geoframe
Log data consisting of log gamma ray (GR), log resistivity (ILD), neutron log (NPHI) and density log (RHOB) measured at "X" well from depths of 1414 - 3820 ft below ground level.

2.1.2 Data core
Data cores consisting of data core porosity and core permeability data are 136 points scattered along the depth of the well.

2.1.3 Data from literature
The data derived from the literature is the value of matrix density, a (tortuosity factor), m (cementation factor) and n (saturation exponent) value.
3. Result and discussion

3.1 Qualitative analysis
Analysis from the log data that has been made into a well composite log, is interpreted based on the direction and shape of the log curve deflection to determine the lithology of the formation in the well X whether it is shale or non-shale, permeable or non-permeable, porous or non-porous, filled with fluid or empty and if filled with fluid including hydrocarbons or water.

After lithological interpretation and interpretation of reservoir fluid composition, the last reservoir zoning is done. Determination of zones aims to assist in making the model that will be made after entering the parameters needed.

Based on the lithological interpretation of well X, there are 5 reservoir zones, all of which are reservoirs composed of sand formations with oil-loaded hydrocarbon fluid, 5 reservoir zones are

- Sand A zone at depth 3497 – 3529 ft
- Sand B zone at depth 3543 – 3584 ft
- Sand C zone at depth 3599 – 3607 ft
- Sand D zone at depth 3623 – 3630 ft
- Sand E zone at depth 3654 – 3685 ft

3.2 Quantitative analysis
3.2.1 Correction of log data with ELAN
The zoned log data will be continued with a correction phase in each zone using ELANplus to correct the petrophysical parameters with the aim of correlating the results of the log data with the core data as validation data. Evaluation of log data is carried out simultaneously by the response equation determined from interpretation models. At this stage, the parameters of the log RHOB (density), NPHI (neutron porosity), PHIT (total porosity) and GR (gamma ray) are corrected.

3.2.2 Result of correlation between the ELAN model and core data
The results of the log data that has been corrected using ELANplus are validated using data core. The ELANplus model that is validated with core data shows the correlation differences in each sand zone.
3.2.2.1 Correlation of ELAN model and data core for Sand A (3497 – 3529 ft)
Based on Figure 2 A which is a log data that has not been validated with data core, the correlation between core porosity and permeability points is not parallel to the permeability curve error of 59.03% and porosity curve error of 14.95%. This is done by ELANplus correction, and it looks quite parallel as shown in Figure 2 B with a permeability curve error of 9.38% and a porosity curve error of 0.78%. It can be concluded that the results of the correction of log data in sand A is good enough because it shows a parallel correlation with the validation data, which is core data and shows changes in the number of errors, which is smaller, which is quite significant after being validated with the data core.

3.2.2.2 Correlation of ELAN model and data core for Sand B (3543 – 3584 ft)
Based on Figure 3 A which is a log data that has not been validated with data core, the correlation between the points of core porosity and permeability is not parallel to the permeability curve error of 217.18 % and the porosity curve error is 10.305%. With this ELANplus correction is done and there is still no significant change as shown in Figure 3 B with a permeability curve error of 52.32% and a porosity curve error of 7.13%. It can be concluded that the results of the correction of log data on sand A have no effect because it does not show a parallel correlation with the validation data which is core data and shows the error number that is still quite large on the permeability curve after being validated with the core data. The reason for not aligning log data and data core data on sand A is due to the lithology of the sand B zone that has a very tight density (too dense) so that the data read on the logging tool is invalid, so it is not possible to make corrections.

Figure 2. Figure of ELAN model correlation and core data from the Sand A zone, Figure A before validation and Figure B after validation.

Figure 3. Figure of ELAN model correlation and core data from the Sand B zone, Figure A before validation and Figure B after validation.
3.2.2.3. Correlation of ELAN model and data core for Sand C (3599 – 3607 ft)

Based on Figure 4 A which is a log data that has not been validated with data core, the correlation between core porosity and permeability points is not parallel to the permeability curve error of 229.16% and the porosity curve error is 13.32%. With this ELANplus correction is done and there is still no significant change as shown in Figure 4 B with a permeability curve error of 198.8% and a porosity curve error of 2.85%. It can be concluded that the results of the correction of log data on sand A have no effect because it does not show a parallel correlation with the validation data which is core data and shows the error number that is still quite large on the permeability curve after being validated with the core data. The reason for not aligning log data and data core data on sand A is because the lithology of the C sand zone has a very tight density (too dense) so the log data that is read on the tool is invalid, so it is not possible to make corrections.

Figure 4. Figure of ELAN model correlation and core data from the Sand C zone, Figure A before validation and Figure B after validation.

3.2.2.4. Correlation of ELAN model and data core for Sand D (3623 – 3630 ft)

Based on Figure 5 A, which is a log data that has not been validated with the data core, the correlation between points of core porosity and permeability is not parallel to the permeability curve error of 65.77% and the porosity curve error is 37.06%. This is done by ELANplus correction, and it looks quite parallel as shown in Figure 5 B with a permeability curve error of 61.54% and a porosity curve error of 29.87%. It can be concluded that the results of the correction of the log data on sand D is good enough because it shows a parallel correlation with the validation data, which is core data and shows the change in error number is smaller after being validated with the data core.

Figure 5. Figure of ELAN model correlation and core data from the Sand D zone, Figure A before validation and Figure B after validation.

3.2.2.5. Correlation of ELAN model and data core for Sand E (3654 – 3685 ft)
Based on Figure 6 A which is a log data that has not been validated with the data core, it is seen that the correlation between core porosity and permeability points is not parallel to the permeability curve error of 213.97% and porosity curve error of 18.54%. This is done by ELANplus correction, and it looks quite parallel as shown in Figure 6 B with a permeability curve error of 54.73% and a porosity curve error of 4.52%. It can be concluded that the results of the correction of log data on sand E is good enough because it shows a parallel correlation with the validation data, which is core data and shows that the number of error changes is smaller after being validated with data core.

![Figure 6](image)

**Figure 6.** Figure of ELAN model correlation and core data from the Sand E zone, Figure A before validation and Figure B after validation.

| Sand     | Log Permeability (%) | Log Permeability After Validation (%) | Log Porosity (%) | Log Porosity After Validation (%) |
|----------|----------------------|--------------------------------------|-----------------|----------------------------------|
| Sand A   | 59.03                | 9.38                                 | 14.95           | 0.78                             |
| Sand B   | 217.18               | 52.32                                | 10.3            | 7.13                             |
| Sand C   | 229.16               | 198.8                                | 13.32           | 2.85                             |
| Sand D   | 65.77                | 61.54                                | 37.06           | 29.87                            |
| Sand E   | 213.97               | 54.73                                | 18.54           | 4.52                             |
| Average  | 157.02               | 75.35                                | 18.83           | 9.03                             |

**Table 1.** Table of data log error values comparison before and after validation with core data.

It can be concluded that in the Sand A, Sand D and Sand E zones in Figure 2, Figure 5 and Figure 6 show a fairly good correlation between the ELAN model and core data after validation, but the Sand B and Sand C zones in Figure 3 and Figure 4 are not there is a fairly good correlation between ELAN model and core data after validation although it still shows a decrease in error value as shown in Table 1 which means that it still shows the change in value to be more valid after validation with data core. This is due to several things such as the lithology curve with tight density [7], so the porosity and permeability of the model cannot be evaluated to make it correlate well with core data, because the model refers to the petrophysical parameters of the log data taken using the logging tool work relies on tool sensitivity, while core data is valid data that comes from sample research in the laboratory so it can't be wrong. Therefore, the results of the ELAN model that are uncorrelated are considered to have
been maximally evaluated and cannot be evaluated again because they can produce unreasonable results.

3.2.3 Water saturation
After validation with core data, the water saturation is calculated manually. Data released only from Sand A to Sand E in the form of uncorrected porosity and permeability data, ELAN corrected porosity and permeability, data core porosity and core permeability data, and resistivity data. Porosity is a comparison between the volume of space (pore) contained in rocks against the volume of rock as a whole [8]. Permeability is the ability of rocks to flow fluid, in milliard units (mD) [9]. Water saturation (SW) is the amount of rock pore volume filled with formation water expressed in fractions [9]. Porosity shows how much the volume of the rock holds hydrocarbons [10]. The greater porosity in reservoir rocks allows the rock to contain more hydrocarbon fluid. Water saturation values indicate the degree of saturation of water in a hydrocarbon fluid [11]. The smaller the water saturation allows more hydrocarbon fluids such as oil and gas. This water saturation indicates where the hydrocarbon zone is located.

| Sand  | Permeability (mD) | Porosity (%) | SW (frac) |
|-------|-------------------|--------------|-----------|
| Sand A| 5010.35           | 37           | 0.17      |
| Sand B| 3458.69           | 27           | 0.23      |
| Sand C| 305.93            | 22           | 0.51      |
| Sand D| 275.04            | 17           | 0.73      |
| Sand E| 4258.02           | 28           | 0.21      |
| Average| 2661.6           | 26           | 0.37      |

Table 2 shows the average permeability and porosity values of each zone, the water saturation value of each zone, and the average value of water saturation in the "X" well. Water saturation values are calculated using the Archie formula:

\[ S_w = \frac{\frac{a \times R_o}{\phi}}{m \times R_t} \]  (4.1)

With \( S_w \) as the water saturation sought, \( R_o \) as the resistivity formation which is saturated with water in this study used data \( R_o = 0.161978804 \ ohm \) which is the resistivity of the formation from other wells because in the well "X" there is no water formation which can be used as a reference resistivity formation which is saturated with water, \( R_t \) as the actual formation resistivity in this study was taken from the ILD (Induction Deep Resistivity) log data of the well "X", \( \phi \) as the total porosity taken from the average porosity values on the PIGE log (effective porosity), \( a = 0.62 \) as a tortuosity factor and takes the value 0.62 because it is a sandstone formation, \( m = 2.15 \) as a cementation factor and takes a value of 2.15 because the average porosity exceeds 16%, and \( n = 2 \) as exponential saturation. Based on Table 2 it can be seen that the average porosity of all zones is 26% according to the reference porosity values above 15% including the category of excellent porosity (good) [12]. For the average value of permeability based on Table 2 is 2661.6 mD which according to reference permeability values in above 1000 mD including very good permeability category [12].

4. Conclusion
Based on the results of data processing and interpretation of the results of the correlation between the ELAN model and the data core, it was concluded that using core data as a validation process, producing more accurate data can be seen by decreasing the error value of the permeability from 157% to 75.35% and porosity from 18.83% to 9.03% after being validated with core data. Sand A, Sand D
and Sand E show the best correlation with a fairly small error value, whereas in Sand B and Sand C there is not a good enough correlation with error values that tend to be large due to lithology at Sand B and Sand C which are lithology tight so that the results of reading the logging tool have a fairly high error, especially in the permeability data which still shows a decrease in the error value after being validated with the data core.

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