Hydrocarbon Reservoir Characterization of ‘Y’ Field in Kutai Basin East Kalimantan Using Artificial Neural Network Method

Y R Hendryan¹, M S Rosid¹, and Haryono²

¹Geophysics, FMIPA Universitas Indonesia, Kampus UI, Depok 16424, Indonesia
²Saka Energi Indonesia, Jakarta 12190, Indonesia

E-mail : syamsu.rosid@ui.ac.id

Abstract. The Kutai Basin in East Kalimantan is one of the largest oil and gas production areas in Indonesia. However, because the area has quite complex geology, the distribution of sandstone reservoirs in this area tends to be random. In the ‘Y’ field there are two wells named TU-1 and TS-1. The presence of gas-type hydrocarbon was shown in the TU-1 well while TS-1 well is a dry well. For this reason, the volume of rock properties were distributed to predict the presence and distribution of sandstones that have the potential to become hydrocarbon reservoirs. This study uses artificial neural network method with seismic attribute volumes, such as instantaneous amplitude, instantaneous phase, and instantaneous frequency, and also acoustic impedance inversion as the input. The volume of rock properties that were successfully predicted by the neural network were density, P-wave velocity, and effective porosity. From this volume, there is one horizon that becomes an interesting area because it has an area that indicates a hydrocarbon reservoir, that is Late Miocene horizon. Its properties have density value range from 2.1 - 2.25 gr/cc, P-wave velocity value ranges from 1800 - 2500 m/s, and effective porosity value ranges from 10 - 15%.

1. Introduction
The Kutai Basin is located in the eastern of Kalimantan Island. The formation of this basin is thought to be caused by the rifting process during the Middle Eocene due to the expansion of the Sulawesi Sea Floor [1]. This rifting process also produces series of half grabens which are then filled with the syn-rift deposit during Eocene. Then the basin subsided in the Late Eocene to the Oligocene period resulting marine transgression deposition. Uplifts and erosion occurred in the central part of Kalimantan during Early Miocene, resulting in a series of deltas which were prograded eastward and filled the Kutai Basin to the present shelf margin and supplied turbidite deposits on ocean bottom [2]. The compression that occurred in the Early Miocene caused the basement fracture that had been formed before to form a basin inversion structure in the North Kutai Basin. In the present the dominant structural trend in the Kutai Basin is a series of tight folds composed of anticline and syncline directed to NNE-SSW. This deformation is not too intense in the offshore area. In land areas, this fold is referred to as the Samarinda Anticlinorium while in the offshore area it is referred to as the Mahakam Foldbelt [3]. Both are productive oil and gas regions. Hydrocarbon accumulation is also controlled by its tectonic activity [4]. Based on such geological processes and the control of sediment distribution by sea level fluctuations, also high sedimentation rates, the distribution of clastic sediments will have a tendency to be random.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
Therefore, the neural network method is used to characterize the reservoir. The neural network better to solve the non-linear problems, so hopefully it can be used to characterize the ‘Y’ field properties in the Kutai Basin since its characteristics is random.

2. Data and Method
The seismic data used in this study is 3D post stack seismic data in the ‘Y’ field, Kutai Basin, East Kalimantan (Figure 1). This seismic data has inlines coverage from 1211 - 1611 and crosslines from 7476 - 8476 with 4 ms of sampling rate.

![Map showing the location](image)

**Figure 1.** Map showing the location [5], geometry design of seismic data acquisition and wells location.

Meanwhile the well data available are only two wells data, namely TU-1 and TS-1 (Figure 1). Acoustic impedance (P-impedance) data from wells will be used as a control in the acoustic impedance inversion process. Then the other well data such as density, sonic P-wave, and effective porosity will be used for the neural network process so that these three properties can be carried out to all seismic volumes to produce rock property volumes. It will be used to characterize the hydrocarbon reservoir. The well data that is becomes the training data for the neural network is TS-1 well data, then the well data to validate the model produced by the neural network is the TU-1 well data. The training and validation process will be considered sufficient if each correlation coefficient value obtained has reached ≥ 0.5.

3. Results and Discussion

3.1. Neural network training and validation
Rock properties that is being predicted by neural network are density (RHOB) (Figure 2), DT/P-wave sonic (Figure 3), and effective porosity (Effpor) (Figure 4). Property density prediction result has a correlation coefficient of 0.68548 for the training process and 0.55191 for validation. The prediction result of the P-wave sonic property has a correlation coefficient value of 0.79123 for the training and 0.52284 for validation. The result of the effective porosity property prediction has a correlation coefficient of 0.60477 for the training and 0.50836 for validation.
Figure 2. Training (left) and validation (right) result with its correlation coefficient of density (RHOB) property.

Figure 3. Training (left) and validation (right) result with its correlation coefficient of sonic (P-wave) property.
3.2. Neural network distribution to seismic volumes

The volume of rock properties are resulted from the distribution of the neural network. This neural network looks for the relationship between input data which are the volume of attributes and the volume of acoustic impedance, and the output data which is rock property data. Relationships obtained by the neural network based on training data and validation will be applied to other traces contained in each input volume. The results of rock property volumes are density, P-wave velocity which is converted before from sonic P-wave, and effective porosity as can be seen in Figure 5, Figure 6, and Figure 7.

Figure 4. Training (left) and validation (right) result with its correlation coefficient of effective porosity (Effpor) property.

Figure 5. Neural network deployment for density (RHOB) property.
Figure 6. Neural network deployment for velocity of P-wave ($V_p$) property.

The volume of property that is produced has characteristics of density value range from 2.1 – 2.6 gr/cc, P-wave velocity value range from 1600 – 3800 m/s, and effective porosity value range from 0 – 0.3 (0 – 30 %). All these rock property volumes are then sliced in certain areas that have characters as a reservoir area.

From the properties that have been obtained, slice is carried out at certain depths that become the area of interest. The slice is a horizon slice that is the Late Miocene horizon. The horizon slice that is filled by density, effective porosity, and P-wave velocity are shown in Figure 8, Figure 9, and Figure 10, respectively. Then all the properties on this horizon will be interpreted with the values in Table 1 to determine which area is the potential area of the hydrocarbon reservoir.
Table 1. Range value of rock properties for few types of lithology [6].

| Type of formation                  | P-wave velocity (m/s) | S-wave velocity (m/s) | Density (gr/cm$^3$) | Density of constituent crystal (gr/cm$^3$) |
|-----------------------------------|-----------------------|-----------------------|---------------------|------------------------------------------|
| Scree, vegetal soil               | 300-700               | 100-300               | 1.7-2.4             | -                                        |
| Dry sands                         | 400-1200              | 100-500               | 1.5-1.7             | 2.65 quartz                              |
| Wet sands                         | 1500-2000             | 400-600               | 1.9-2.1             | 2.65 quartz                              |
| Saturated shales and clays        | 1100-2500             | 200-800               | 2.0-2.4             | -                                        |
| Marls                             | 2000-3000             | 750-1500              | 2.1-2.6             | -                                        |
| Saturated shale and sand sections | 1500-2200             | 500-750               | 2.1-2.4             | -                                        |
| Porous and saturated sandstones   | 2000-3500             | 800-1800              | 2.1-2.4             | 2.65 quartz                              |
| Limestones                        | 3500-6000             | 2000-3300             | 2.4-2.7             | 2.71 calcite                             |

Table 1 informs the range of P-wave velocity values, S wave velocity, and density in several types of lithology. The values in this table are a reference in characterizing the reservoir area on the volume of rock properties produced. The reservoir focus is sandstone reservoirs which in Table 1 are porous and saturated sandstones lithologies which have P wave velocity values around 2000 - 3500 m/s and density value around 2.1 - 2.4 gr/cc.

Figure 8. Horizon slice of density (RHOB) volume.

Figure 9. Horizon slice of effective porosity (Effpor) volume.
Figure 10. Horizon slice of P-wave velocity \( (V_p) \) volume.

The area indicated as a reservoir is an area bordered by a red-dashed circle. Based on Figure 8 this area has low density value around 2.1 – 2.25 gr/cc which is marked by blue – green color. Low density indicates that rock is not solid so that it has the potential to become a reservoir. The area of Figure 9 also verified by the high effective porosity value around 10 – 15%, which is shown in yellow – orange color. Effective porosity indicates the pores in rocks that are interconnected which means the fluid can flow in it. The P-wave velocity in this area is also fairly low which is around 1800 – 2500 m/s, shown in blue – green color of Figure 10. P-wave is a compression wave that is associated with rocks and the contents of the pore. P waves will propagate quickly on solid material or materials that have low compressibility. So if the reservoir rocks contain fluid in the form of water which is incompressible, then the speed of the P wave will be high. The speed of the P-wave will be decrease if it passes through the oil and gas fluid. All properties support each other and increase the possibility that the marked area is a reservoir area that may contains hydrocarbon.

4. Conclusion
From the results it can be concluded that the neural network is able to predict rock properties, in this case density, P-wave velocity, and effective porosity. The volume of all the three rock properties are made to slice a horizon and see the potential of hydrocarbon reservoir. In the horizon of Late Miocene, there is an area of interest that bounded by red-dashed circle. It properties has low density value which ranges from 2.1 – 2.25 gr/cc, effective porosity value ranges from 10 – 15 %, and P-wave velocity range from 1800 – 2500 m/s. For future work, the number of wells can be added and try to add more attributes to increase correlation coefficient of neural network so the confidence level will higher.

Acknowledgement
We wish to thank PT Saka Energi Indonesia for their favor to use the data and publishing in this paper. We also thank to DRPM Universitas Indonesia for the PITTA grant no. NKB – 0640/UN2.R3.1/HKP.05.00/2019.
References

[1] Hall R 2002 Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific: computer-based reconstructions, model and animations J. Asian Earth Sci. 79.

[2] Moss S J and Chambers J L 1999 Tertiary facies architecture in the Kutai basin, Kalimantan, Indonesia J. Asian Earth Sci. 17(1–2) 157–181.

[3] Ott H L 1987 The Kutai Basin: a unique structural history Ann 16th. Conv. Proc. 1 307–316.

[4] Satyana A H, Nugroho D and Surantoko I 1999 Tectonic controls on the hydrocarbon habitats of the Barito, Kutei, and Tarakan Basins, Eastern Kalimantan, Indonesia: major dissimilarities in adjoining basins J. Asian Earth Sci. 17(1–2) 99–122.

[5] McClay K, Dooley T and Fer A 2000 Tectonic Evolution of the Sanga Sanga Block, Mahakam Delta, Kalimantan, Indonesia. AAPG Bull. 84.

[6] Bourbié T, Coussy O and Zinszner B 1987. Acoustic of Porous Media.