Reservoir Distribution Analysis with Seismic Colored Inversion in Fluvial Deposition Environment West Natuna Basin

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Abstract. West Natuna Basin is a fluvial deposition environment with thin-bed sand reservoir overlapping with shale and shaly sand. Inversion is applied using Seismic Colored Inversion which considered to provide with robust result to identify geological features such as sand channels’ continuity with low-acoustic impedance value alongside zone of interest. Seismic Colored Inversion can be made by inverting seismic data into Acoustic Impedance value which can be obtained by deriving data from well, as control, then utilized it to change the seismic data volume to Acoustic Impedance volume. By performing a lateral slicing along the target horizons, the distribution of sand channels can be identified. Therefore, the promising reservoir zone with low Acoustic Impedance value and the non-reservoir zone can be clearly distinguished. Slicing was performed in A1 horizon, showing low AI sand channels ranging from 12.000 up to 15.500 ((ft/s)*(g/cc)) spreading at the center of the map through the East. Slicing in B2 horizon, showing what appears to be sand channels with low AI value ranging from 16.000 up to 17.800 ((ft/s)*(g/cc)) spreading at the center of the map between the U1 and U3 well, and appears at the Northeast of the map.

1. Introduction
One of the most important hydrocarbon reservoirs are fluvial deposits, which can be found in many parts of the world such as Alaska, Argentina, southern USA and Gulf Mexico, North Sea, China, Venezuela [1]. In fluvial deposits environment, the most significant hydrocarbon reservoir could be found in sand bodies with the form of interconnected channels because of the materials with excellent porosity and permeability, isolated by boundaries in between the fluvial bodies. The boundaries usually take in the form of fault because of their influence towards the movement of the fluids and the hydrocarbon productions. Due to complexities in fluvial deposition environment, in depth and detail understanding upon characteristics of the reservoir in fluvial deposition environment are needed to develop the potential oil and gas field. Further information about different channel orientations, thickness, and the continuity of channels become somewhat important because this sinuous sand body channels contain significant amounts of hydrocarbon in fluvial deposition environment.

Seismic Inversion is a technique to create earth’s subsurface model using input of seismic data and well data as a control. This inversion technique can generate Acoustic Impedance, which can be utilized to create subsurface image. This method is capable to produce not only the boundaries...
between lithologies but also the physical parameters of the lithology itself. Acoustic Impedance and its derivations can be used to identify the characters of the reservoir and its distribution. In oil and gas industry, seismic inversions have already been used numerous of times. These inversion methods require specialists’ job with years of experience in seismic inversions to utilize and interpret the result optimally.

Figure 1. Index map that shows the location of this study’s area of interest in West Natuna Basin, which located at the center of Sunda Shelf [2].

1.1. Regional Geology
The location of this study is in West Natuna Basin, this basin is an Indonesian rift basin with commercial quantities potential for undiscovered oil and gas [3,4]. This basin is located at the center of Sunda Shelf, in the South China Sea. There are many tectonic elements in this specific area which caused structural complexities. The structures in West Natuna Basin are dominated by fault, there are strike dip faults and spreading center faults oriented in North-South. This has shown that this field of study is formed during the postrift. Subduction area is also caused pressure from the plates.

1.2. Petroleum System
Generally, there are two main source rock that produced the hydrocarbon in West Natuna Basin. These are the source rock from the Eocene and Oligocene. Benua Formation shale and Lower Gabus, which are syn-rift sediments from late Eocene until early Oligocene, are potential source rocks located in the Northern part of West Natuna Basin [5,6]. Reservoir in West Natuna Basin are in the synrift and postrift of Gabus formation and Barat Shale forms significant regional seal [5,6]. The traps in West Natuna Basin are dominated with stratigraphic traps.

2. Data and Methods
The available data for this study is 3D post stack seismic data, consisted of 457 inline and 4290 crossline and covering an area of 210 km2. The well data is consisted of four wells with the available logs are porosity log, gamma ray log, and water saturation log. In this study, the integration of seismic data and well data is produced in time structure map and Acoustic Impedance distribution map.
The inversion method performed to generate Acoustic Impedance distribution map using Seismic Colored Inversion. This technique was first developed by Steve Lancaster and David Whitcombe from BP Amoco. Seismic Colored Inversion is a post-stack inversion that is fast and relatively easy to perform in comparison with other inversion methods, but not the best in its class [7]. However, this method is robust in terms of quality of the result if compared to the Sparse Spike Method.

Figure 2. Matching operator of Seismic Colored Inversion.

The operator phase is -90°, this can allow integration with reflectivity series to generate the impedances [7] which makes sense because inversion produces rock properties instead of interface properties in the case of seismic cube [8]. Further reflectivity study shows that the gross value of Acoustic Impedance log is constant for wells within a particular field [9]. This is, therefore, prove that a single average operator can be applied over the entire seismic data to perform an inversion. This approach assumes that the wavelet is zero phase. To obtain the Seismic Colored Inversion Operator, Acoustic Impedance logs along the zone of interest and enough seismic traces are needed to produce better estimation from the mean of seismic response. Once the operator is obtained, this can be applied to the seismic volume without the need to perform inversion to the whole seismic volume. Since hydrocarbons are often stratigraphically trapped in West Natuna Basin, accurate and better image of the sand bodies are needed. Thus, the implementation of Seismic Colored Inversion provides a proper image target of sand bodies and stratigraphic features [8]. Implementation of Seismic Colored Inversion requires the wells to be tied to the seismic cube, then it automatically generates the Acoustic Impedance logs needed. Inversion operator that has been obtained is applied to produce a virtual colored inversion cube. This saves a lot of time because the result can be quickly examined, and other unnecessary computation of inversion volume can be avoided [8].

3. Result and Discussion

Minimum resolution that can still be detected by seismic wave is the tuning thickness, with its value equals a quarter of the seismic wave itself. In other words, tuning thickness is the minimum limit of lithology thickness that can still be distinguished by seismic wave. Seismic wave’s velocity from the intervals between horizon A1 and horizon C1 can be acquired from sonic log with the value of 2977 m/s. Dominant frequency of the wavelet from operator used for Seismic Colored Inversion is 25 Hz. Therefore, the tuning thickness is 29.77 m. Based on geological data, the thickness of sand channels in this field of study is ranging from 0 – 30 m. From tuning thickness analysis, wavelet from the operator that used in Seismic Colored Inversion should be able to cover the sand channels in the field of study.
optimally, in hope that the sand channels can be seen from the inversion result laterally by slicing the horizon to analyze the reservoir distribution.

Figure 3. Cross plot P-impedance vs Porosity with Gamma Ray as the color key.

Figure 4. Cross plot P-impedance vs Porosity with Water Saturation as the color key.

Analyzing the characteristics of reservoir zone from the field of study can be done through cross plot analysis. From Cross plot P-Impedance vs Porosity, sand and shale cannot be separated well because of the sand and shale are interbedding with shaly sand. Gamma ray log is a record of radioactivity level that can be useful to determine the lithology. Gamma ray will show the respond of shale sensitively because shale usually contains much higher level of radioactivity than sand. Sand can be associated with the low value of gamma ray log while shale can be associated with high value gamma ray log. Since the geological condition of the target formation in this field of study is dominated by the interbedding of sand and shale. Figure 3 shows that the overlapping of sand and shale can be seen where the high value porosity of sandstone is also associated with high value of gamma ray. Although the value of porosity appears high, the gamma ray value is also high. This indicates that sand with high porosity is contaminated by shale.

The color key of Cross plot P-Impedance vs Porosity then changed to water saturation log in order to determine the fluid content of the lithology. From the cross plot, the value of water saturation log shows that fluid contents from the lithology is dominated by water. This condition can be affected by the geological features of target formation. Sand that is contaminated with shale can affect the log reading. The condition where sand is contaminated with shale can decrease the value of resistivity, so the water saturation value appears higher. Therefore, the saturation of hydrocarbon will be lower than the actual data. In clean formation, sand without shale contamination or even with the contamination of shale no higher than 15%, water saturation log can be trusted but, in this case, the reason is because of wet rock’s conductivity is not linearly related to water conductivity. This condition exists because conductivity of clay content in formation is causing the estimation of water saturation appears higher because clay conductivity is not considered [10].

The result of inversion shows the distributed Acoustic Impedance along the cross section that can distinguished the reservoir and non-reservoir zone. Shale lithology can be associated with low value of Acoustic Impedance while sand lithology can be associated with high value of Acoustic Impedance. The boundaries between each layer can be seen clearly. Slicing is done to horizon A1 and B2 in order to analyze the lateral distribution of sand channels, which is the character of reservoir in West Natuna Basin.
The slicing of Horizon A1 shows the area with low value of Acoustic Impedance with yellow to red in color that indicates sand lithology. From the Figure, interesting geological features can be detected. Meandering sand channels can easily be observed. Fluvial deposition environment in West Natuna Basin is dominated by sand channels with meandering shape [11]. The distribution of sand channels in Horizon A1 slicing shows the ranging value of 12.000 to 15.500 ((ft/s)*(g/cc)). Significant sand channels are dominated at the center of area in between of U3 well and U7 well and continue the spreading through the Eastern part of the map. From the slicing of Horizon B2, the value of low Acoustic Impedance with the ranging value of 16.000 to 17.800 ((ft/s)*(g/cc)) can be seen with the color of yellow. Sand channels appear to be accumulated at the Center of the map between U1 well and U3 well through to the Northeast part of the map.
4. Conclusion
Inversion technique using Seismic Colored Inversion shows prominent result with relatively quick process. Potential reservoir zone and non-reservoir zone can easily be differentiated by looking at the distribution of sand channels with low acoustic impedance value. The characteristic of fluvial deposition environment in the shape of meandering sand channels can be identified through lateral slicing that was performed in A1 horizon, showing low AI sand channels ranging from 12.000 up to 15.500 ((ft/s)*(g/cc)) spreading at the center of the map through the East. Slicing in B2 horizon, showing what appears to be sand channels with low AI value ranging from 16.000 up to 17.800 ((ft/s)*(g/cc)) spreading at the center of the map between the U1 and U3 well, and appears at the Northeast of the map..

References

[1] Bridge J S 2001 Latin American Journal of Sedimentology and Basin Analysis 8 (2) 87-114.
[2] Hall R 1996 Geological Society, London, Special Publications 106 (1) 153-184.
[3] Sladen C 1997 Geological Society, London, Special Publications 126 (1) 49-76.
[4] Maynard K, Siregar P, Andria L 2002 Proc. of the Ind. Petro. Assoc. 87-104.
[5] Michael E and Adrian H 1996 Proc. of the Ind. Petro. Assoc. 25 (1) 465-479.
[6] Phillips S, Little L, Eric M, Odell V 1997 Proc. of the Ind. Petro. Assoc. 26 (1) 381–389.
[7] Lancaster S and Whitcombe D 2000 SEG Tech. Prog. Exp. Abs. Society of Exploration Geophysicists 1572-1575.
[8] Nour A and Al-Awfi S 2013 Implementing Seismic Colored Inversion to enhance reservoir property estimation in frontier exploration areas: A case study in central Saudi Arabia Unayzah reservoir SPE Middle East Oil and Gas Show and Conference Society of Petroleum Engineers.
[9] Walden A T and Hosken J W J 1985 Geo. Pros. 33 400-435.
[10] Chukwuemeka P A, Abayomi O I, Uduma O E 2018 Iraqi J. of Sci. 59 510-519.
[11] Darmadi Y, Willis B J, Dorobek S L 2007 J. of Sed. Res. 77 (3) 225-238.