Inversion Analysis on Promax 3D Software for Determine Variation Amplitude with Offset Lambda MU RHO of High Resolution at West Natuna Arang Islands

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Abstract. A fields, which is called as gas fields, is in the western basin of Natuna. This basin has a main reservoar, such of sandstone reservoar. The thickness reservoar on this fields is very varied, so a result of inversion could only mapping the thickness which is near on tuning thickness. Based on sensitivity test on target area, Acoustic Impedance (AI) parameters on the research wells is insensitive to distinguish a hydrocarbon, so acoustic parameters with only Primer (P) velocity could not be applied in this reservoar characterization fields. But, when the Secondary (S) velocity, λρ and µρ were involved, hydrocarbon distribution could be mapped. This is what then underlies the using of Avo LMR prestack inversion method in Promax 3D software, in conducting reservoar characterization analysis. Velocity S data was needed in AVO LMR inversion method. Secondary (S) velocity data could be generated with using some method, but on this research the method used limited with only castagna method. The result of the research was obtained some conclusion that target area were obtained range value of rho lamda (λρ) 5 – 3 GPA gr/cc and mu rho (µρ) 15.8 – 17 GPA gr/cc. Its shows the existence of sandstone caracterization and hydrocarbon anomaly at Lower Arang Formation.

Key words : Sand stone, rho lamda (λρ), mu rho (µρ), AVO inversion.

1. Introduction
Since 1976, the bright spot has been known as an indication of subsurface gas accumulation based on seismic data. In fact, There is not every bright spot signify existence accumulation of natural gas. Ostrander (1984) and Neidel (1986) found a new concept that was considered better than the bright spot to identification natural gas. This concept is called the Amplitude Variation with Offset (AVO) which is widely used in the search for hydrocarbon accumulations, especially gas, namely by analyzing changes in the amplitude of primary wave energy with the angle of arrival or offset.

Ostrander (1984) states that the response of amplitude at the different boundary layer is depending on the incident angle and associated with the Poisson ratio. The main purpose of AVO analysis is to obtain subsurface rock properties using conventional surface seismic data. In other hands, It also
shows that AVO techniques can be used to estimate reservoir areas. AVO inversions from the Zoeppritz equation are can be applied to obtain the AVO pre-stack seismic data reflectivity attribute.

AVO analysis is a relatively new technique, used in oil exploration for reservoir characterization, especially to give information on hydrocarbons (especially gas) and lithology discrimination. In 1997, Goodway et al. introducing inversion techniques using Lambda, Mu, and Rho parameters. The Lambda Rho parameter (fluid incompressibility) is sensitive to perform of fluid-factor discrimination in a reservoir so it can be used to detect fluid content in the reservoir and Mu Rho shows rigidity and can be used to distinguish lithology. The research purposes is to identification characteristics of sandstone reservoir in the lower charcoal formation by inverse AVO lambda mu rho method.

2. Research Methodology
From seismic data gather that has been done pre-conditioning in 3D promax software in the previous process, It combined into super gather on inversion processing so that the signal to noise ratio is large. Then, stacking velocity is done and its horizon is determined by considering the well data obtained so that it can determine the permeable sand layer target and possibly indicate hydrocarbons. From the data gather, AVO analysis is done by knowing the intercept and the gradient in the target area (top target). Then by knowing the intercept and gradient, the P-wave reflectivity (Rp) and S-wave reflectivity (Rs) can be estimated. Inversion is carried out to obtain P-wave impedance (Zp) and S-wave impedance (Zs). The last lambda mu rho (LMR) transformation was carried out and interpreted by considering the analysis of the cross-plot of log and geological information of the area. Flowchart of the research methodology in Figure 1.
3. Regional Geology

3.1. Regional Stratigraphy

The seismic correlation of the AAA well also shows the thin elastic basal section present in the west of the HHH well. This non-prospect rock class becomes thicker than the AAA well towards the east, the well at the Gabus layer as same as the HHH well. This relation can create a stratigraphic trap both areas for hydrocarbons migrating out of the basin depth.
3.2. Prospect Geology
The main prospect units are Oligocene and Early Miocene. Lower Arang and Gabus sand have an age between the Miocene age. Early mapping mismatches at around 3,660 feet and the unfavorable sequence is complex at 6,890 feet. A flat protruding, seismic amplitude anomaly showing special phase changes now passing through both the southern and northern peaks, perhaps in the bottom of the Lower Arang or upper Gabus. AAA wells have porous and permeable sandstones starting with a maximum thickness of 86 meters in the Lower Arang Gabus interval.

![Figure 2. stratigraphy of Natuna Island](image)

4. Theoretical Basis

4.1. Amplitude Variation with Offset (AVO)
The basic principle of AVO originally came from an anomaly, namely the increase in the amplitude of the reflection signal to the increase in the distance of the seismic wave source to the receiver (offset), if the seismic wave is reflected by a rock layer containing gas. The source distance to this receiver (offset) is related to the incident angle of the seismic rays in the reflecting plane. At greater offset, there is a wide incident angle.
The equation derived from the classical approximation of Aki & Richards (Aki. K and PG Richard, 1980):

\[ R(\theta) = P + G(\sin^2\theta) \]

Where is:

\[ P = \frac{1}{2} \left( \frac{\Delta a}{a} + \frac{\Delta \rho}{\rho} \right) \]

\[ G = \left[ \frac{1}{2} \frac{\Delta a}{a} - \frac{\Delta \beta}{\beta} - \frac{1}{2} \frac{\Delta \rho}{\rho} \right] \sin^2\theta \]

Where P is an approach from normal reflection coefficient P-P incidence and It is a P wave reflectivity. G is the gradient or slope of $\sin^2\theta$. Rutherford and Williams (1989) classified changes in AVO anomalies which were modified by Kinman (1995) and Castagna (1997). Being 4 AVO classes namely: class I for high impedance sand with AVO reduction, Class II for almost zero impedance contrast and class III for low impedance gas sand with AVO increase. While class IV for low impedance gas sand with AVO decrease.

4.2. Lambda Mu Rho
The concept of incompressibility and rigidity, which are expressed successively by $\lambda\rho$ and $\mu\rho$, helps in understanding why AVO responses occur. For example, the differences between AVO responses usually observed in sandstones and carbonate rocks can be explained, as the following: rocks and liquids are difficult to compress. However, gas can be compressed easily, so the presence of gas in rocks, such as some sandstone, causes a significant reduction in its incompatibility. Gas in the rock does not affect stiffness, so the result is a significant AVO response, which depends on the contrast between incompatibility and rigidity. In comparison, the AVO response of gases containing carbonate
stones, such as limestone, has usually been observed to be much less significant than those seen for sand and especially sand gas. This is because the gas in these rock pores is rarely compressed significantly because almost all of the seismic wave compressive energy is transmitted through an incompressible rigid carbonate matrix. Using the concept of incompressibility and rigidity is used to help in understanding the different AVO responses observed in the two different types of lithology.

4.3. Seismic Resolution

Seismic resolution is the ability to separate two adjacent reflectors. In the seismic world, the resolution is divided into two: vertical (temporal) and lateral (spatial) resolution. Vertical resolution is defined by seismic wavelength (λ), where λ = v/f where v is the seismic wave velocity (compression) and f is the frequency. Lateral resolution is known as the Fresnel (r) zone with calculations (Avseth, P, T murkerji, G Mavko, 2006):

$$r = \left(\frac{\lambda}{2}\right) \sqrt{\frac{\lambda}{f}}$$

Where t is travel time of seismic wave (TWT/2)

5. Results and Discussion

5.1. Sensitivity Test

Data sensitivity test is an important process because at this stage the determination of existing data can be used or not. The sensitivity test is done by cross-plotting some physical rock parameters obtained from well data, such as Vp/Vs ratio, P impedance and S, porosity, water saturation, lambda rho, mu rho, etc. Cross-plot is done to see whether the data used has a quantitative relationship and sensitivity to be able to distinguish rock lithology and fluid influence. Figure 3 is the cross-plot between Gamma Ray (GR) vs. P impedances; it shows 2 colors, yellow and green. The green indicates an impermeable layer and the yellow indicates a permeable layer. On the permeable layer look green dots and colors other than green. This color indicates the resistivity according to the color index that is next to the plot. From the figure, it appears that the green has a low resistivity which means that the layer has large water saturation while the anomaly that is sought has a large resistivity. On this cross-plot, the anomaly is less visible. In Figure 4. There is cross-plot between Vp / Vs with Impedance P. Qualitatively shale can be distinguished by the ratio of Vp / Vs 2 - 5 and gas sandstone between 1.6 - 2. This result is very close to the Goodway 1997 range that gas sandstone has a Vp / Vs ratio of around 1.7. So that it can be concluded while the log has gas sand.

| Vp/Vs | (Vp/Vs)^2 | σ | λ+2μ | μ | λ | λ/μ |
|-------|------------|---|-------|---|---|-----|
| Shale | 2.25 | 55.1 | 0.38 | 20.37 | 4.035 | 12.3 | 3.1 |
| Gas Sand | 1.71 | 2.9 | 0.24 | 18.53 | 6.314 | 5.9 | 0.9 |
| Change/ Average (%) | -27 | -55 | -45 | -9.5 | 44 | -70 | -110 |

In Figure 5, there is cross-plot between Lambda Rho and Mu Rho. Lambda-Rho signifies the resistance of a rock to the compressive force affecting it. The easier it is to compress, the smaller the value. Meanwhile, Mu-Rho has the material resistance to unchanging shape to stress. The closer the matrix is the low / Mu-Rho rigidity value. From the information above, the anomaly that is sought is the cross-plot of height Mu-Rho and low Lambda-Rho. From Figure 5, the cross-plot in the sand layer is found in the hight Lambda-Rho. While the anomalies that have low lambda rho just a few. We can be concluded that in the well may have gas even if only a little. From some of the cross-plots above, it can be deduced from well, there is a possibility that there is only a hint of gas. And also the lambda mu rho parameter can be seen in this data.
5.2. *Mu* - Rho (μρ)
The value of *Mu* - Rho in Figure 6 is in the range of 2.5 to 17.7 (GPa * g / cc). The value of *Mu* - Rho in the target zone is relatively high, which is above 15 GPa*g/cc, which ranges from 15.8 – 17 GPa*g / cc, this indicates that the matrix in the target area is quite tenuous. So that it can be concluded that the area is sandstone.

5.3. *Lambda* - Rho (λρ)
*Lambda* - Rho value in the figure 7 is in the range of 2.5 to 17.7 (GPa * g / cc). From the picture below it can be seen that the value of *Lambda* - Rho in the target zone is very low, that is below 10 GPa * g / cc which is around 5 - 3 GPa * g / cc, this indicates that the target zone has a hydrocarbon content that is quite good in the form of gas.

Figure 3. Cross-plot GR vs P. Impedance Courtesy Hampson Russell
Figure 4. Cross plot Vp/Vs vs. P. Impedance Courtesy Hampson Russell

Figure 5. Cross Plot Mu-Rho vs Lambda Rho Courtesy Hampson Russell
Figure 6. Parameter Mu – Rho seismic data Courtesy Hampson Russell

Figure 7. Parameter Lambda Rho seismic data Courtesy Hampson Russell
6. Conclusion

From the description of the results and discussion above, the writer can draw conclusions: (1) Based on the sensitivity test in the target area, the AI parameters in the research well are not sensitive to differentiate hydrocarbons, so that the acoustic parameters with P speed alone cannot be applied in the characterization of this field reservoir. (2) In the target area obtained by the range of lambda rho values 5 - 3 GPA g/ cc and mu rho 15.8 - 17 GPA g/cc which indicates the characterization of rock sand and HC anomaly in the Lower Arang formation. When doing AVO inversion analysis or suggestions from the author, namely: Make sure the amplitude conditioning process as described above must be done properly. Because the AVO method is very sensitive to changes in seismic amplitude so the results are good. Vs. is not provided in this data. Although Vs. is needed in the AVO method. The author suggests log data Vs don't just estimation by Castagna only. But it is better to look for other methods so that there are differences and can be seen which is better.

References

[1] Aki, K and PG Richards 1980, Quantitative Seismology : Theory and Methods Journal. Page 304 – 308, WH Freeman and Co.

[2] Avseth, P, T Murjeki, G Mavko (2006), Quantitative Seismic Interpretation, Cambrige University Press.

[3] Neidell, N.S. 1986, Amplitude variation with offset. Geophysics – The Leading Edge of Exploration, March.

[4] Rajagukguk, J. and Sari, N.E., 2018, March. Detection System of Sound Noise Level (SNL) Based on Condenser Microphone Sensor. In Journal of Physics: Conference Series (Vol. 970, No. 1, p. 012025). IOP Publishing.

[5] Ostrander, W.J., 1984, Plane Wave Reflection Coefficients for Gas Sands at Non Normal Angles of Incidence, Geophysics, 49, page 1637-1648.

[6] Riyanto, F.X. Eka Martha, 2008, Amplitude Amplitude of Variation With Offset Fluid Inversion For Determined Hydrocarbon Reservoir Characteristic. Skripsi UI.

[7] Rutherford, S. R. and William. R. FL, 1989. Amplitude- Versus- Offset Variations in Gas Sands, Geophysics, Vol. 54. page 680-688.

[8] Russell, B.H., 1988, Introduction to seismic inversion methods: Society of Exploration Geophysicist Notes Series, Vol 2. Domenico, S.N. Ed., 10.1-10.15.

[9] Saputro, Bambang H. M. 2005, Identification of Hydrocarbon Potential Using Amplitude Analysis Versus Offset. INTEK No:2.

[10] Shuey, RT, 1985 A simplification of the Zoeppritz equations. Geophysics, 50, 509-624 Sumatra Gulf Oil. 1991, Drilling Proposal Natuna Sea Block A.

[11] Sheriff, R.E., and Geldart, L.P, [1995] Exploration seismology, second edition: Cambridge University Press.

[12] Telford, W. M., Geldart, L., P., Sheriff, R. E., and Key. D. A. 1976 Applied geophysics. (London: Cambridge Univ. Press).