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Application of Seismic Post-Stack Inversion for Gas Reservoir Delineation: A Case Study of Talang Akar Formation, South Sumatera Basin

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Abstract. Nauli Field is one of the marginal fields that is located in the western region of Indonesia and has been proven to produce oil and gas hydrocarbons. The field is located in the South Sumatra Basin with reservoir target is sandstone from Talang Akar Formation. The purpose of this study is to integrate petrophysical interpretation and seismic data analysis. Reservoir characterization was performed based on porosity and water saturation for each layer within the wells. Seismic inversion methods chosen to estimate the attributes of P-impedance (Zp), S-impedance (Zs) and density (ρ). Amplitude Versus Offset (AVO) inversion through Lambda-Mu-Rho (LMR) attribute can provide information on lithology and fluids content in the reservoirs. The connection between seismic inversion and AVO inversion was to validate the gas content from the seismic data and its lateral dispersion. Data processing and analysis shows that the effective porosity for Nauli Field is between 10 to 20 porosity unit (p.u) with 20-70% water saturation. The thickness of net pay is 2-8 meters. Post-stack inversion shows impedance anomaly around 1580-1590 ms with value 22.000-25.000 (m/s)*(g/cc). Petrophysical analysis estimated this anomaly as layer-x sandstone with gas fluid saturated. LMR attribute confirm this fluid with lower Lambda-Rho values around 11-20 (Gpa)*(g/cc) than Lambda-Rho values around 28-32 (Gpa)*(g/cc).

INTRODUCTION

Nauli field discovered in 1972 and one of production block within Western Indonesia Area located at Kabupaten PALI (Pendopo, Abab, Lematang Ilir), South Sumatera province (Fig. 1). It is located in the South Sumatera Basin, with Talang Akar Formation as its main sandstone reservoir.

FIGURE 1. Location map of Nauli field in South Sumatera province (IHS Map, 2004)

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Main reservoir target within this field is sandstone from Talang Akar Formation in South Sumatera Basin. Oil and gas is produced with natural flow from four oil and gas wells. The problems in this research are limited and obsolete data, low reservoir pressure, water influx and old production facilities which impacted to the successful of development well drilling, work over well and to the achievement of hydrocarbon production target. Maximizing the current production and find upside potential of the field is the challenge of this study, by doing some petro physical analysis and integration with 2D seismic inversion.

Seismic inversion is a technique, which transformed seismic data to rock physical properties to formed earth model. It is a technique that has been used by geophysicist to transform seismic data into P impedance (product of density and P wave velocity), which is then used to make predictions about lithology and porosity [1].

METHODS

In this research, model based post-stack and simultaneous pre-stack inversions were chosen to determine physical properties of the rocks. A model-based inversion uses a forward model to calculate synthetic seismic data as part of its inversion algorithm [2]. While pre-stack seismic inversion is done to obtain reliable estimates of P-wave velocity (Vp), S-wave velocity (Vs), and density (ρ) from which to predict the fluid and lithology properties of the subsurface of the earth [2]. Seismic post-stack inversion was done with the principal of one dimension convolution model as per equation below:

$$S(t) = R(t) * W(t) + N(t) \quad (1)$$

S(t) is the seismic trace, W(t) is the seismic wavelet, R(t) is the earth coefficient reflection and N(t) is the noise component while the * symbol representing convolution process.

Aki-Richard equation was used in the simultaneous seismic inversion. This equation was based on Fatti equation. The equation is as per below:

$$Rpp(\theta) = c1Rp + c2Rs + c3Rd \quad (2)$$

Rpp is total reflectivity, θ is the angle, Rp is the P-wave reflectivity, and Rs is the S-wave reflectivity. Amplitude Versus Offset (AVO) inversion through LMR attribute input into simultaneous inversion to characterize gas fluid in Talang Akar Formation [3]. The available seismic line is show in Table 1 with total length 55.400 meters.

The main input in this study is the seismic, well data and horizons. Hydrocarbon bearing reservoirs were identified both qualitatively and quantitatively by re-evaluated available well log data and combine with well test and production history for each wells. There are four available well data i.e. Well 1, Well 2, Well 3, and Well 4. Well log type consist of Gamma Ray, Spontaneous Potential, Resistivity, Neutron and Density Log. The qualitative analysis was performed by scanned through the well logs signatures. Hydrocarbon reservoir zone is characterized by lower gamma ray and spontaneous potential value, high resistivity, and crossover between neutron and density log [4]. The quantitative analysis involves the calculating parameters such as shale volume, water saturation and effective porosity [4]. Water saturation value is calculated by considering that the Talang Akar Formation typically shaly formation. Poupon-Leveaux (Indonesia) model was chosen to estimate water saturation [5]. The value such a=1, m=1.8 and n=1.8 were used for the model. These values were calculated from special core analysis (SCAL) data from adjacent field. Cut off value for reservoir zone is 18% for shale volume, 11% for porosity and 60% for water saturation.

TABLE 1. List of seismic line data and identification

No	*Line No*	SP *Range*		*No of SP*	*SP Interval* (m)	*Total Length* (m)
		FSP	LSP			
1	1	2003	2243	240	17.50	4.200
2	2	2001	2187	186	17.50	3.255
3	3	2001	2193	192	17.50	3.360
4	4	2001	2269	268	17.50	4.690
5	5	2001	2215	214	17.50	3.745
6	6	51	953	898	17.50	26.940
7	7	51	359	307	17.50	9.210
TOTAL				**2.305**		**55.400**

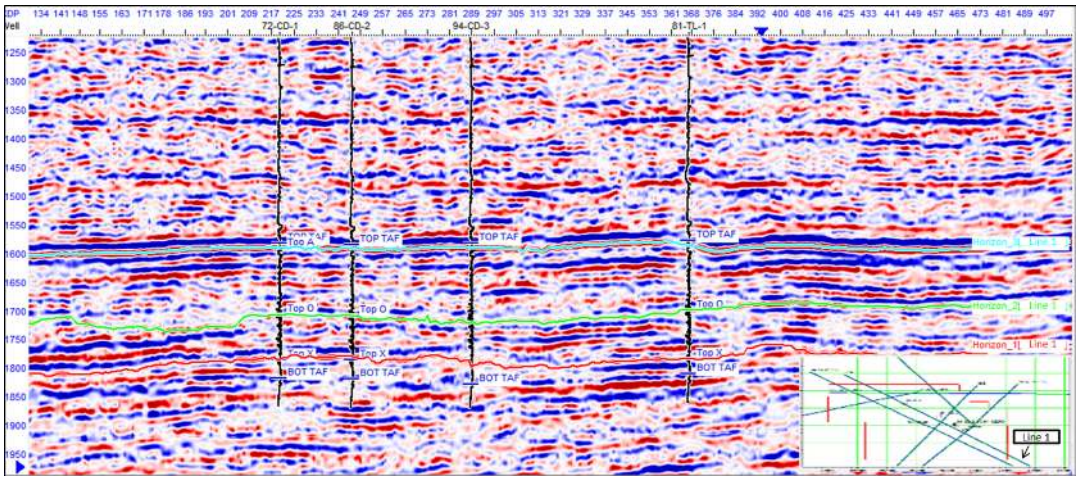

FIGURE 2. Identification of seismic horizons sampled from 2D seismic line 1, defined three seismic horizon.

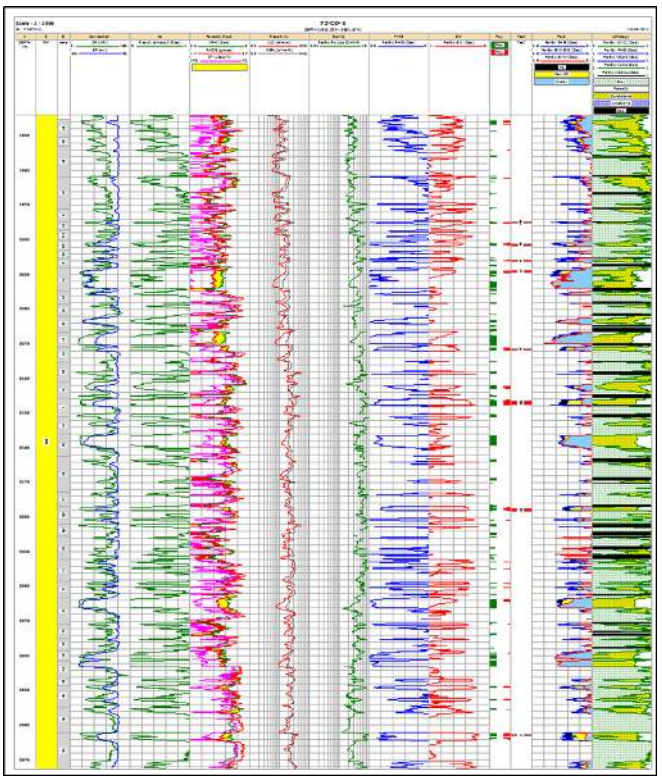

FIGURE 3. Quantitative analysis result from well 1 and fluid identification combined with well test data for determination of hydrocarbon bearing layers

In order to investigate inversion response on the seismic data, seismic-to-well tie was performed on the wells. Statistical wavelet with zero phases was extracted to align reflection on the synthetic to the composite trace. After good correlation reach between wells and seismic, seismic horizon were identified and marked on each 2D seismic line. First horizon with blue color is lower part of Talang Akar Formation, second horizon with green color is the middle part and third horizon with yellow color is the upper part of Talang Akar Formation (Fig. 2).

P-Impedance model was generated from model based post-stack seismic inversion. Initial P-Impedance model from well log data was used to attenuate the frequency component of reflectivity. Initial model was deprived with 800-2200 ms window parameter of sampling rate with 2 ms and High Cut Frequency range from 10-15 hz.

Pre-stack simultaneous inversion was used to determine P-impedance, S-impedance and density. Seismic offset gather convert to super gather to increase signal to noise ratio and minimize random noise. Super gather

was done by divided to ten offset range from 277 to 1957 meter and rolling window in five Common Depth Point (CDP). Seismic post-stack inversion give only P-impedance (Zp) value meanwhile simultaneous inversion will give Zp, Zs and density [6]. These results imply into AVO inversion with Lamda-Mu-Rho attribute volume.

RESULTS AND DISCUSSION

Well log evaluation of Well 1, Well 2, Well 3, and Well 4 shows that Top of sandstone reservoir from Talang Akar Formation in Nauli Field is around 1853-1860 mSSTVD meanwhile the bottom of reservoir is around 2327-2348 mSSTVD. Reservoir quality from the upper to lower characterize by increasing shale content with rage of value 0.4 – 0.6 (40-60 %). Effective porosity value is 10 – 22 pu (porosity unit) and water saturation value is around 30-70%.

Reservoir cut-off value determined from core analysis data suggest that for shale volume, minimum allowable value is 18 %, porosity is 11% and water saturation is 60%.

In Fig. 3, the quantitative analysis result from well 1 showed total potential layers within Talang Akar Formation are twenty nine layers with shale volume range from 40-60 %, effective porosity range from 10-22% and water saturation range from 30-70 %. Prospect gas bearing layer are layer A, E, F, K, O, P and X, associated gas bearing layer are layer D, G, J, L, N, and Q meanwhile oil bearing layer are layer S, T and V.

Seismic inversion result that applied to all 2D seismic line shows good result and able to differentiate rock layer. Model based post-stack seismic inversion shows color contrast variation, which is representing the impedance variation from one layer to another (Fig. 4). Simultaneous seismic inversion shows P-impedance value (Zp) for good reservoir is around 8115-8700 (m/s)*(g/cc) (Fig. 5) and S-impedance value (Zs) around 4600-5200 (m/s)*(g/cc) (Fig. 6).

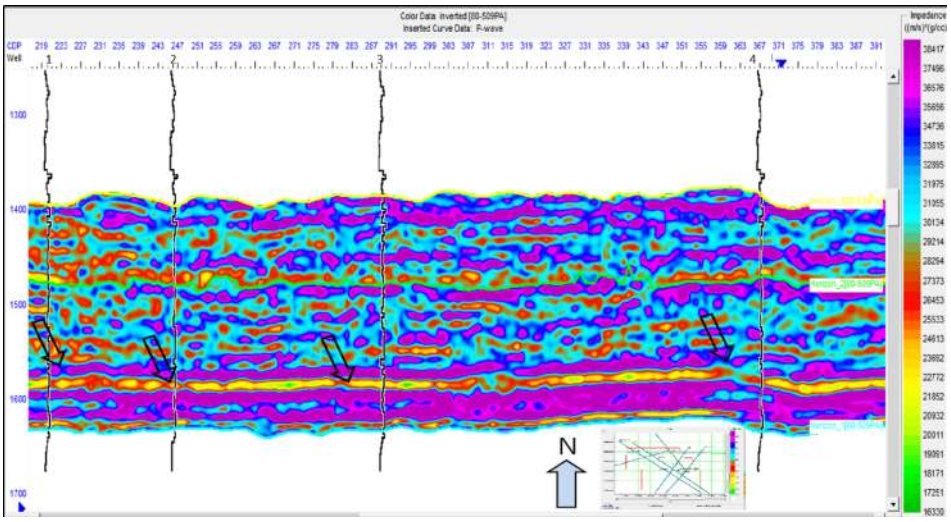

FIGURE 4. Model based post-stack inversion result with arrow sign was the interested zone with low impedance value.

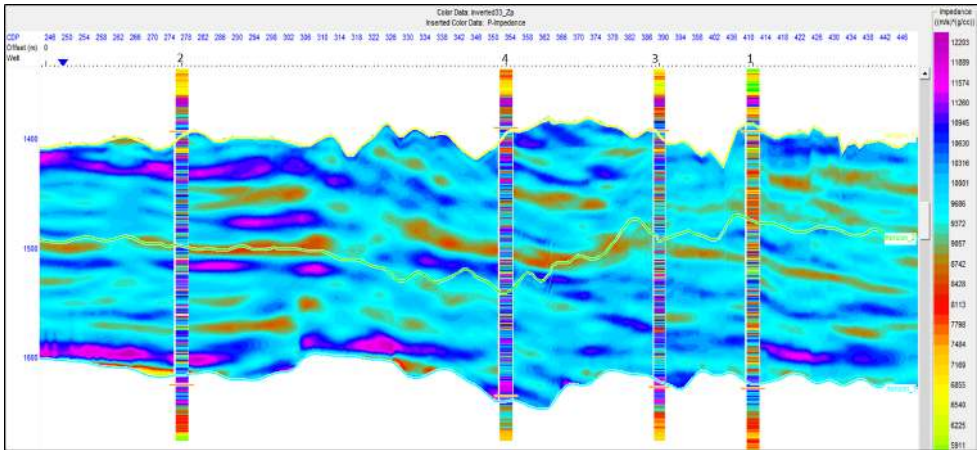

FIGURE 5. P-impedance value from pre-stack simultaneous inversion from line 7

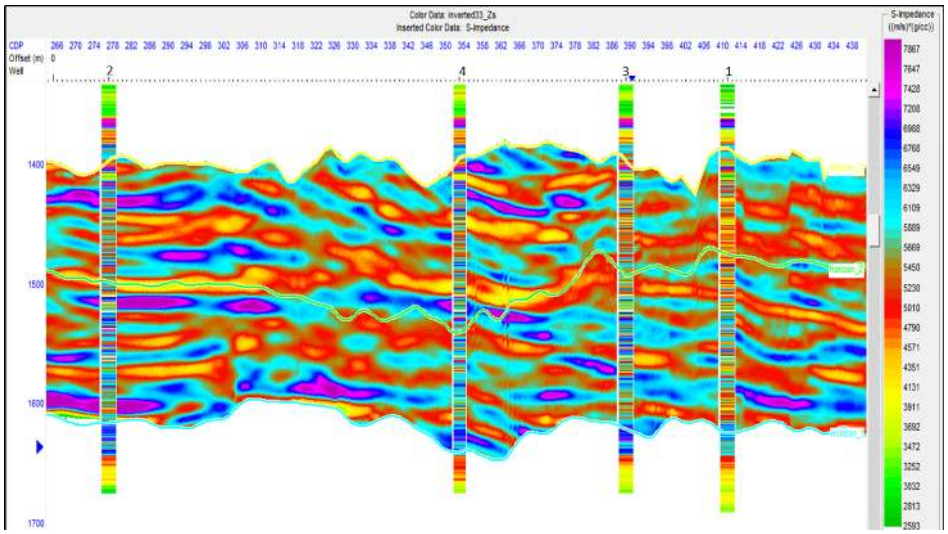

FIGURE 6. S-impedance value from pre-stack simultaneous inversion from line 7

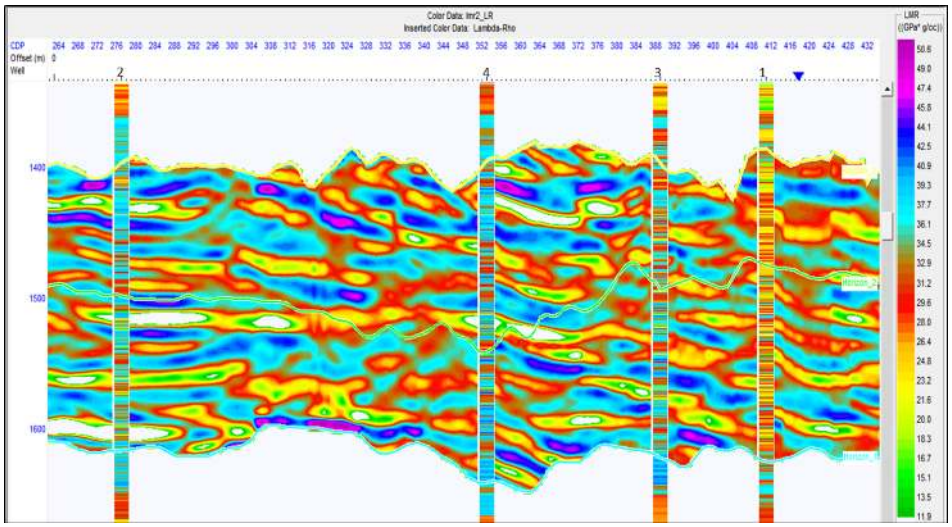

FIGURE 7. Lambda-Rho inversion result from line 7

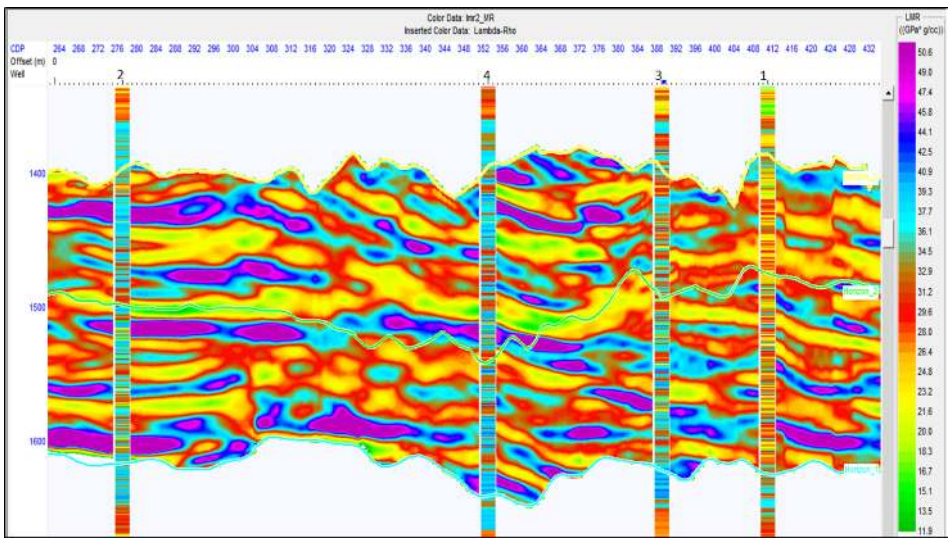

FIGURE 8. Mhu-Rho inversion result from line 7

AVO Inversion through LMR attribute input into simultaneous parameters show the value of Lambda-Rho (Fig. 7) is 11-20 (Gpa)*(g/cc), lower enough than Mu-Rho attribute value (Fig. 8) with 28-32 (Gpa)*(g/cc). Lambda-Rho contrast value indicated the present of gas fluid hydrocarbon through layer of interest except for well 4 with Lamda-Rho and Mu-Rho attribute value relatively the same for interest layer.

Lower impedance value associated with good porosity sandstone and higher impedance value associated with shale or sandstone that contain shale (shaly sand). Lower impedance value at 1580 ms – 1590 ms with yellow to reddish yellow color has impedance value from 22.000 – 25.000 (m/s)*(g/cc) and spread from west to east of Nauli field, lower enough from surrounding impedance value which is around 36.000 – 38.000 (m/s)*(g/cc).

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