RESERVOIR CHARACTERIZATION USING SIMULTANEOUS INVERSION TO DELINEATE HYDROCARBON RESERVOIR

KARAKTERISASI RESERVOAR MENGGUNAKAN SEISMIK INVERSI SIMULTAN UNTUK MENENTUKAN PENYEBARAN RESERVOIR HIDROKARBON

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ABSTRAK

Analisis karakterisasi reservoar dilakukan untuk mengidentifikasi litologi dan kandungan fluida di Formasi Talang Akar Cekungan Sumatra Selatan. Metode yang digunakan pada penelitian ini adalah metode inversi simultan. Data yang digunakan pada penelitian ini adalah *angel gather* dan data log di sumur Puja A dan Puja B. Parameter elastis yang dihasilkan dari inversi simultan adalah Impedansi P, Impedansi S dan V_p/V_s rasio. Parameter lambda-Rho ($\lambda\rho$) dan Mu-Rho ($\mu\rho$) diturunkan dari impedansi P (I_p) dan impedansi S (I_s). Lambda-Rho sensitif terhadap perubahan fluida sedangkan Mu-Rho sensitif terhadap perubahan litologi. Pada penelitian ini, target reservoarnya adalah Formasi Talang Akar yang mengandung gas dan memiliki nilai Lambda-Rho ($\lambda\rho$) antara 5-15 (GPa*g/cc) dan nilai Mu-Rho ($\mu\rho$) 35-45(GPa*g/cc). Perbandingan kecepatan gelombang P (V_p) dan gelombang S (V_s) ketika melewati fluida dapat digunakan sebagai indikator untuk mengetahui kandungan fluida. Batuan yang mengandung gas memiliki nilai V_p/V_s lebih rendah dibandingkan dengan batuan yang mengandung air. Pada penelitian ini zona yang mengandung gas memiliki nilai V_p/V_s 1,5-1,7.

Kata Kunci: Inversi simultan, Lambda-Rho, Mu-Rho, V_p/V_s

ABSTRACT

*Reservoir characterization analysis has been carried out for identifying lithology and fluid content on TalangAkarFormation in South Sumatra Basin. Robust method that being used in this study is the simultaneous inversion which uses pre-stack gather and well log data from Puja A and Puja B. Elastic parameters resulted from simultaneous inversion are P Impedance, S Impedance and V_p / V_s ratio. Lambda-Rho parameter ($\lambda\rho$) and Mu-Rho ($\mu\rho$) derived from P impedance (I_p) and S impedance (I_s). Lambda-Rho is sensitive to fluid content while Mu-Rho to lithology. Area of interest in this study is Talang Akar Formation as reservoir which contains gas with Lambda-Rho ($\lambda\rho$) between 5-15 (GPa*g/cc) and Mu-Rho ($\mu\rho$) 35-45 (GPa*g/cc). The ratio of P wave (V_p) and S wave (V_s) can be used as an indicator to determine fluid saturation. Gas saturated rock has value of V_p / V_s lower than the water saturated rock. In this study, the ratio of V_p / V_s is 1.5-1.7 for gas saturated rock.*

Keyword: *Simultaneous Inversion, Lambda-Rho, Mu-Rho, V_p/V_s*

I. INTRODUCTION

Talang Akar Formation is potential reservoir to produce gas and oil. More than 75% of oil production in South Sumatra is from this formation (Bishop 2005). The process of sedimentation in Talang Akar Formation took place during the period of Late Oligocene to Early Miocene. The formation was deposited, unconformably not harmony above Lahat

Formation. Talang Akar Formation is most fluvial sediment in the lower part, whereas the upper part is delta environmental sediment and shallow marine environment. Talang Akar Formation is one of the best reservoirs in South Sumatra Basin, because its porosity more than 25% and permeability 1-50 mD (Bishop 2005; Ginger & Fielding 2005).

This research started from Amplitude Versus Offset (AVO) method and then using Simultaneous Inversion to distinguish lithology and fluid on Talang Akar Formation. Lithology identification and fluid content can be determined by V_p/V_s parameter, value Lambda-Rho and Mu-Rho. Castagna (1985) and Li (2004) use V_p/V_s, ratio as an indicator to find out the corelation between, fluid content, lithology, porosity, and shale volume. The rock which has high porosity and low V_p/V_s value, the change of V_p/V_s, ratio in general is more influenced by shale volume content than porosity rock.

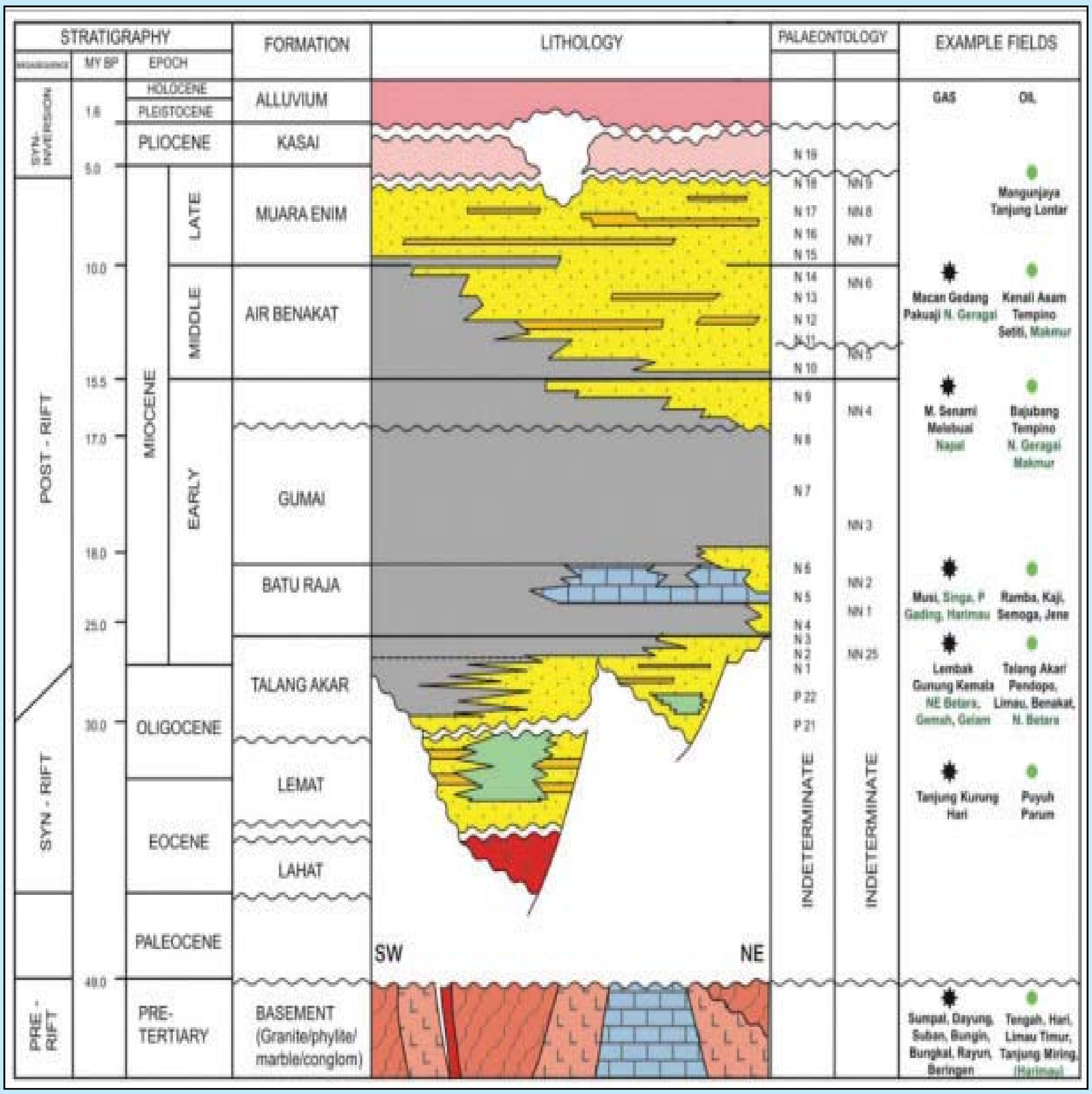


Figure 1
Stratigraphy of South Sumatra Basin (Ginger & Fielding 2005)

AVO method was firstly introduced by Zoeppritz in 1919. AVO principle illustrates reflection coefficient and transmission as function from incidence angle in elastic media (density, P-wave velocity, and S-wave velocity. Aki and Richard (1980) formulated the concept reflection coefficient and transmission more complete for P-wave velocity that fall on solid limited field. Ostrander (1984) used AVO analysis to find out seismic amplitude curve to additional incidence angle and the rock which contains gas. The change of AVO curve was affected by P-wave, S-wave, density contrast, and Poisson Ratio. There is phenomenon that the rock was saturated by gas will increase seismic amplitude on far offset.

Fatti (1994) developed Aki-Richard equation separating P-Wave reflectivity coefficient, wave reflectivity S (R_s), and density (R_D). Then it changes the equation of reflectivity R_p, R_s, and R_p became P-impedance function, S impedance, density contrast. Goodway (1997) identified lithology, and fluid content by using lame's parameter (Lambda-Rho, and Mu-Rho). Gray, Endersen (2001) stated lambda-Rho is multiplication Modulus Lame's rock with density then called compressibility.

Incrompresibility is rock resistance to the change of volume which is caused the change of pressure. Lambda-Rho provides more information about fluid content. Mu-Rho is multiplication between modulus shift with density. Mu-Rho provides information about density of rock. Sand stone has higher Mu-Rho so it is difficult to become slide over, whereas shale has low Mu-Rho so it is easy to become slide over. Mu-Rho is sensitive to the change of lithology, however it is not affected by the change of fluid content. Lambda-Rho and Mu-Rho are obtained from the relation between P-Impedance (I_p) and S(I_s) Impedance.

II. METHODOLOGY

The study (research) used well log data Puja A and B Well log data consists of log gamma ray, density, neutron porosity, P-wave, and resistivity like in Figure 2. Those wells do not have logV_s, log V_s is estimated by using Castagna's equation. Seismic data which are used in this study (research) are 3D CDP gather with the amount inline 239 (2180-2419) and crossline 579 (10042-10621). Seismic data have been carried out in residual static step, migration process and Normal Move Out (NMO) correction.

A. The Analysis of Physical Rocks

The purpose of the analysis of physical rocks is to identify lithology and fluid content using well data. The analysis of physical rock was carried out by crossplotting between parameters log. This used log V_p/V_s. P-Impedance, Lambda-Rho and Mu-Rho. V_p/V_s, Lambda-Rho and Mu-Rho were obtained from I_p and I_s using the following equation;

$$\lambda\rho = I_p^{\,2} - 2I_s^{\,2} \qquad (1)$$

$$\mu\rho = I_s^{\,2} \qquad (2)$$

Crossplotting between V_p/V_s versus P-Impedance parameter can distinguish sandstone and shale. The parameter of elastic rock can be found out by conducting crossplot between Lambda-Rho versus Mu-Rho.

B. Simultaneous Inversion Process

Before conducting inversion process of seismic data, pre-processing was carried out. Data in the form of CDP gather was processed to be super gather to increase signal to noise ratio. The initial step of inversion process was to change angle gather to offset. Algorithm which was used was using ray-tracing by using RMS velocity. Seismic data in angle function, was then divided by 4 groups namely angle 5^0-10^0, 10^0-15^0,15^0-20^0, and 20^0-25^0. The ne□t step was wavelet estimation from each group of incidence angle. Wavelet estimation is an important thing in the process of inversion because it will determine the quality of inversion result. In this study, wavelet was e□tractedusing statistic method around Puja A and puja B wells.Wavelet which was used has wavelet length 200 ms, taper length 25 ms, sampling rate 2 ms and zero phase seismic polarity.

The ne□t step was building low frequency model. Low frequency model resulted from interpolation and e□trapolation from P-impedance log, S impedance and density. The above sandstone layer gas A and the above sandstone gas B were used as interpolation guidance P-impedance value. S impedance and density for seismic volume. The process of building low frequency model was conducted using high pass filter 5 □z and high cut 10 □z.

Before doing inversion process, quality control pre-inversion was carried out. This step was conducted to see correlation between synthetic seismogram with

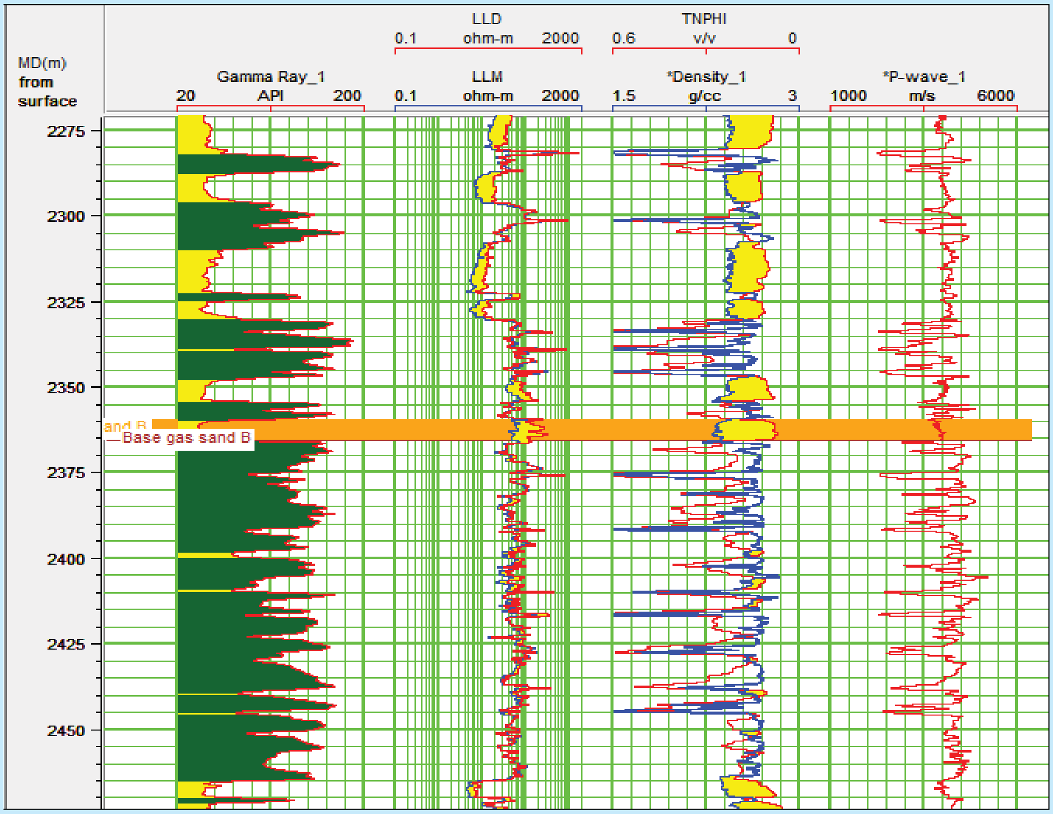


Figure 2
Well data used gamma ray, resistivity, density and V_p

the real seismic trace. Correlation value between seismic trace and synthetic seismogram on Puja A well was 0,81 and on Puja-B well 0,84. The final step was doing simultaneous inversion process (Hampson & Russell 2005). The final result from simultaneous inversion process were P-impedance, S-impedance, and V_p/V_s.

III. RESULTS AND DISCUSSIONS

A. The Analysis of Lithology Sensitivity and Fluid

The result of crossplot between P-impedance versus V_p/V_s and Gamma Ray as the third parameter was to distinguish between sandstone and shale. Sandstone has low gamma ray value compared with shale. In Figure 3 showed V_p/V_s can distinguish between sandstone and shale. V_p/V_s value on sandstone between 1,5-1,7 in accordance with the lab-measurement (Li 2004) P (I_p) impedance was multiplication between density with rock velocity. P-impedance was affected by velocity and rock density. Rock which has high porosity has low impedance value. P-impedance value of sandstone based on the crossplot between 8000-1000 ((m/s*(g/cc)). However, in the crossplot, P-impedance cannot distinguish sandstone with shale well. The other cross-plot was lambda-Rho versus Mu-Rho both was used to distinguish lithology and fluids (Goodway 2001). Rock which contains gas has Lambda-Rho 5-17 (GPa*g/cc) whereas shale has Lambda-Rho value more than 17 (GPa*g/cc). Mu-Rho is elastic parameter which showed solidity of matrix rock. Sandstone has Mu-Rho value 35-45 (GPa*g/cc) whereas shall has Mu-Rho lower than 25 (GPa*g/cc).

B. AVO Analysis

The purpose of AVO analysis is to find out the change of amplitude reflection coefficient to additional incidence angle.The rock which contains gas has rock density and lower Poisson Ratio compared when filled with water. The great of reflection coefficient was affected by velocity, density, and Poisson Ratio. When the wave propagates on normal angle, so reflection coefficient the above layer of sandstone which contains gas with shale will be negative. When the incidence angle was not the same with nil (non-zero offset) its reflection coefficient value increasing or more negative.The form of AVO curve in research area is AVO curve on class III (Rutherford & Williams 1989).

C. The Result of Simultaneous Inversion

The result of simultaneous inversion was P-impedance S-impedance, V_p/V_s ratio. Elastic parameter Lambda-Rho and Mu-Rho was modified from the number between P-impedance and S-impedance. Based on the sensitivity of log data physics parameter rock well which can distinguish between sandstone and shale was V_p/V_s Lmbda-Rho and Mu-Rho.

The result of crossplot on well data is used as reference to analyze inversion result. Figure 6 is the profile of V_p/V_s which across Puja A & B wells. Log gamma ray was used as lithology control. From this figure in two ways time (TWT) 1715 ms-1720 ms is the top and bottom of sandstone gas and TWT 1800

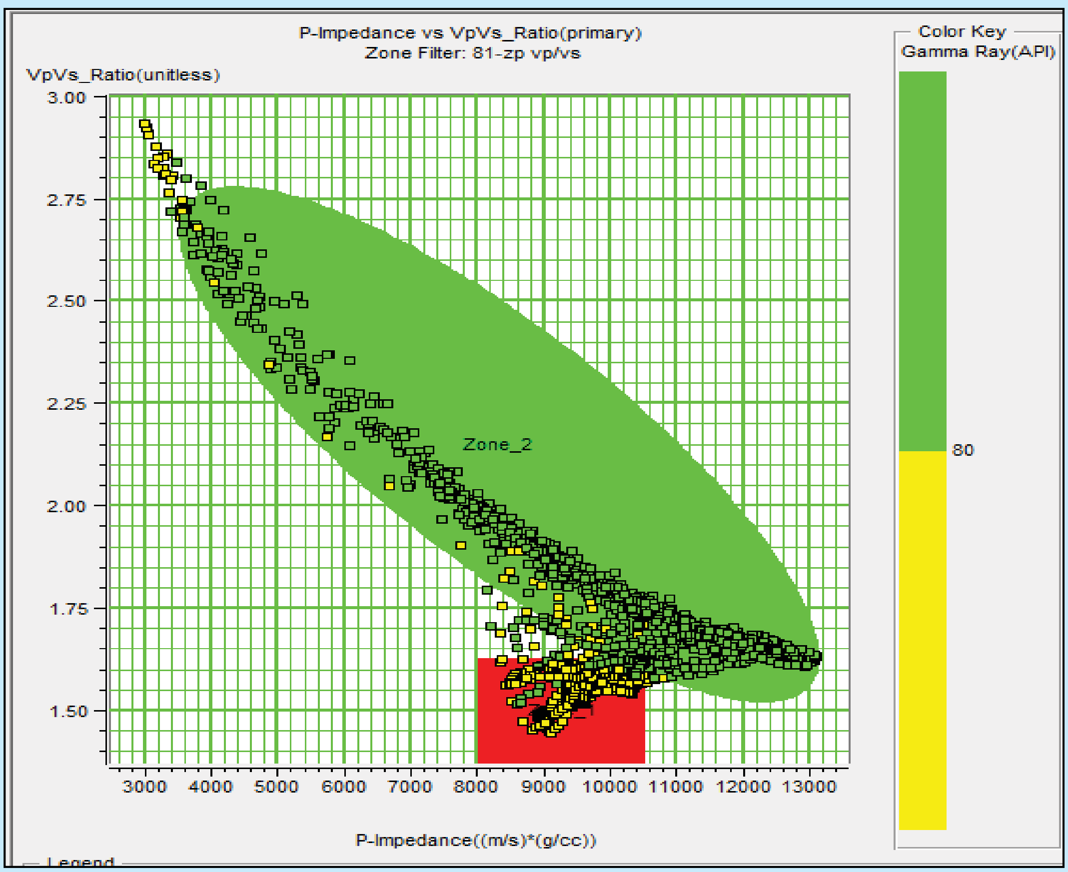


Figure 3
Crossplot between P-impedance and V_p/V_s ratio

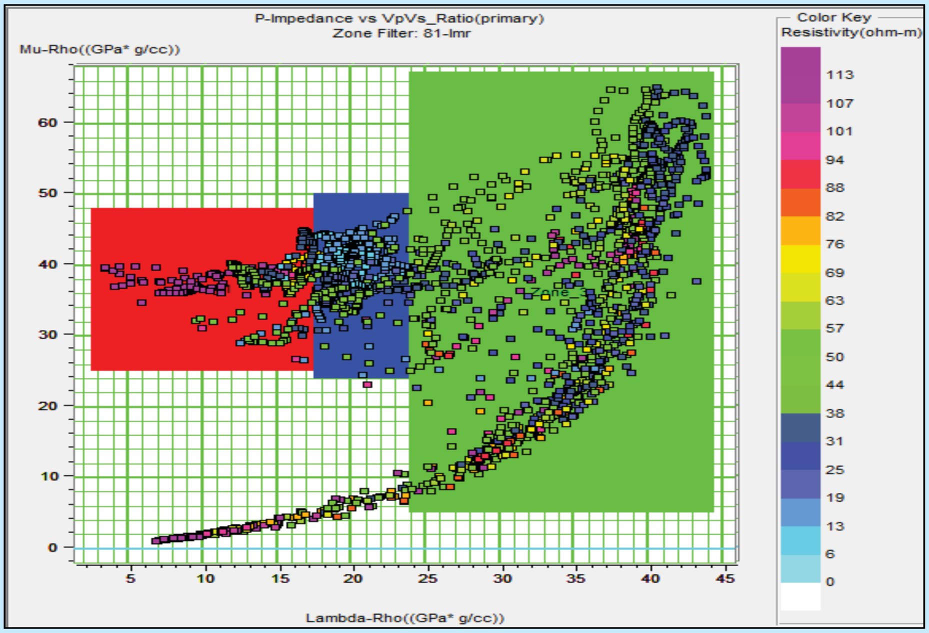


Figure 4
Crossplot between Lambda-Rho and Mu-Rho

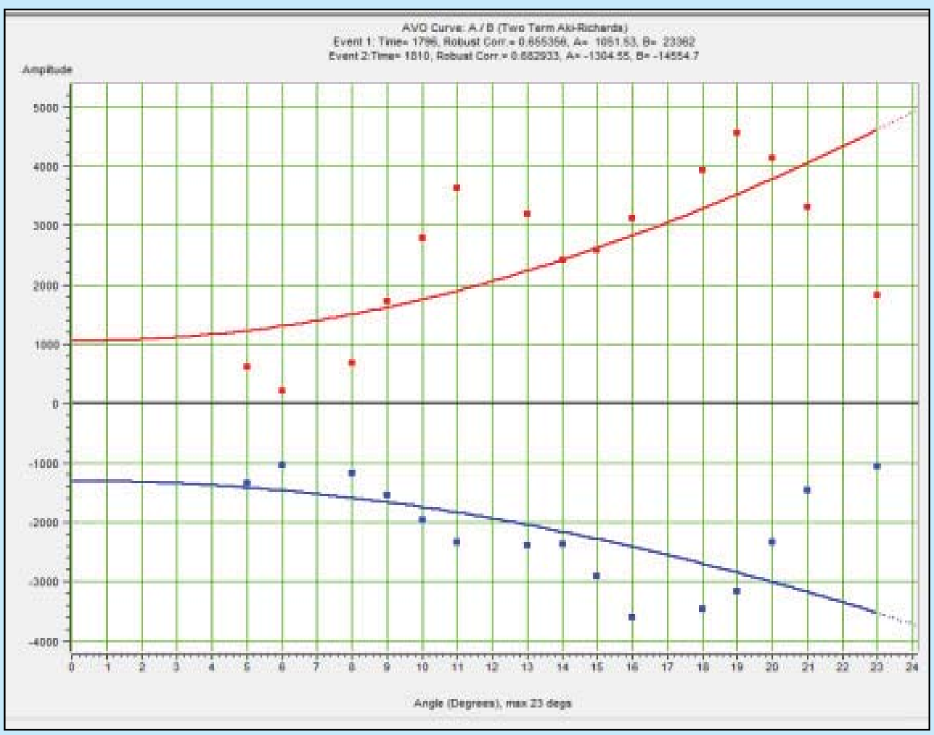


Figure 5
The curve relation between reflection coefficient and incoming angle

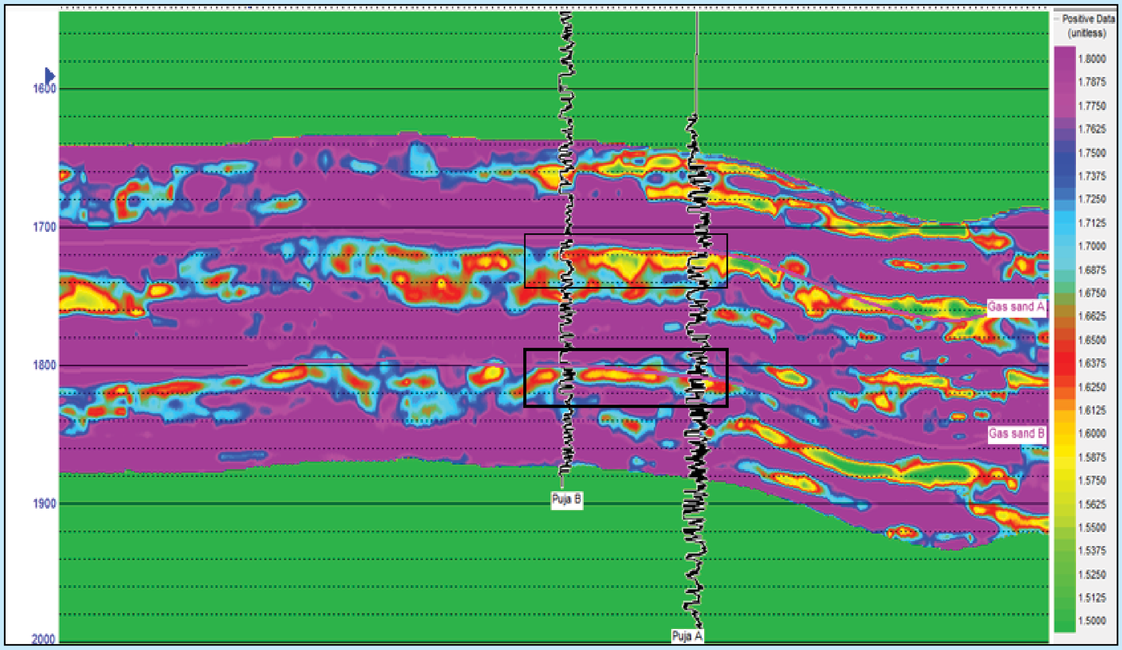


Figure 6
V_p/V_s ratio which passed Puja A and B wells

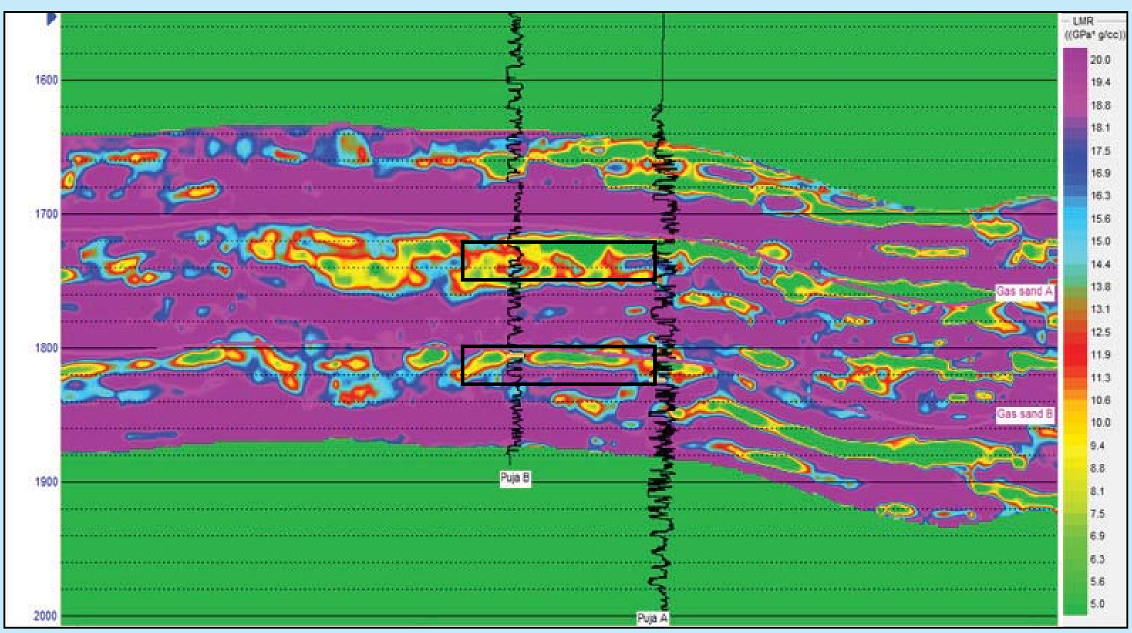


Figure 7
Lambda-Rho which passed Puja A and B wells

ms-1820 ms is the top and bottom of sandstone gas B respectively. V_p/V_s value on the limit on sandstone gas A and limit on sandstone gas B is 1.5-1.7. Sandstone layer gas A and sandstone layer gas B were estimated zone which contain gas. In addition, to using V_p/V_s value for predicting fluid content using Lamda-Rho parameter. The rock which contains gas was easier to squeeze compared with the rock which containts water. At the time the rock was easier to squeeze so Lambda-Rho value of the rock was small. Figure 7 is the profile of Lambda-Rho which across Puja A and B Well. From the above, it is known that Lambda-Rho value on the above limit of sandtone gas A and the above limit of sandstone gas B 5-15 (GPa*g/cc). Lambda-Rho value was greater from 18 (GPa*g/cc), estimated as shale. The area which has lower Lambda-Rho in value accordance with low V_p/V_s value in Fgure 6.

In study research (study) lithology identification uses Mu-Rho. Mu-Rho was obtained from multiplication square S impedance. Mu-Rho parameter related to solidity of matrix rock. Sandtone has higher solidity value compared with shale. Figure 8 was the profile of Mu-Rho which across Puja A and B wells. From the figure, it was known Mu-Rho on the upper limt sandstone gas A and on the upper limit sandstone gas B between 35-45 (GPa*g/cc). The area which has Mu-Rho value less than 35(GPa*g/cc). It was estimated as shale. The high Mu-Rho was in accordance with lower log gamma ray on well data.

Defining lithology and fluid were carried out by extracting or slicing Lambda-Rho volume , V_p/V_s ratio and Mu-Rho horizontally as long as the upper limit layer on sandstone gas B. The time window which used 20 ms, below the upper limit sandstone gas B. Figure 9 (a) was the spread V_p/V_s ratio, Figure 9 (b) was Lambda-Rho spread map and Figure 9 (c) was the result from Mu-Rho. From the three maps were seen that the area around Puja A and B wells were prospect area. The area around Puja A and B wells have Lambda-Rho value and lower V_p/V_s, whereas Mu-Rho value around the well which has higher value compared with the are around

IV. CONCLUSIONS

AVO analysis can find out gas content in Talang Akar Formation. The change of AVO curve in the research area was AVO class III. Additional, incidence angle compared with the increase reflection coefficient. Beside, simultaneous inversion can be used to identify lithology and fluid. The rock which contains gas has V_p/V_s 1.5-1.7, value. Lambda-Rho 5-15(GPa*g/cc) and Mu-Rho 35-45(GPa*g/cc).

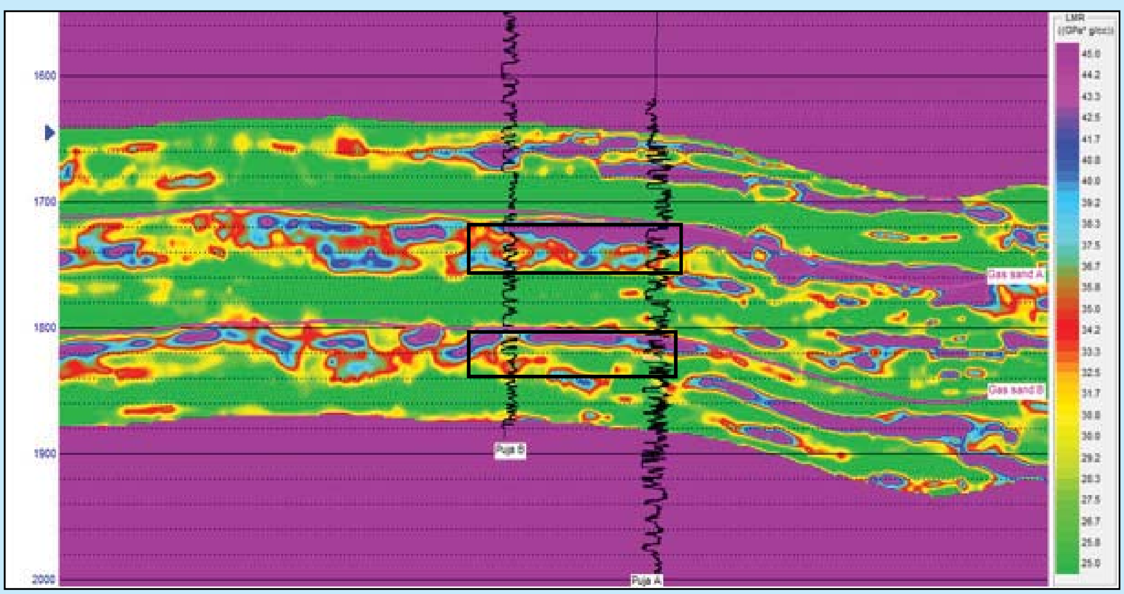
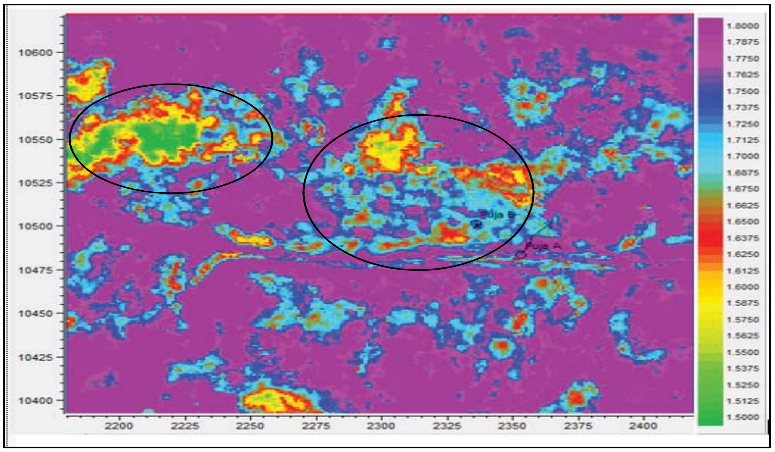
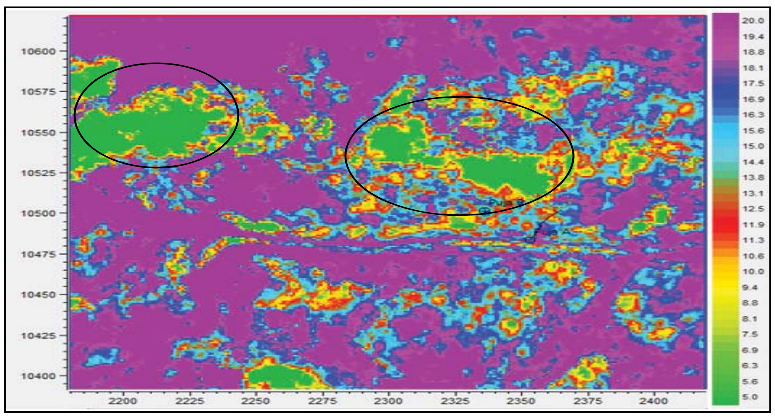


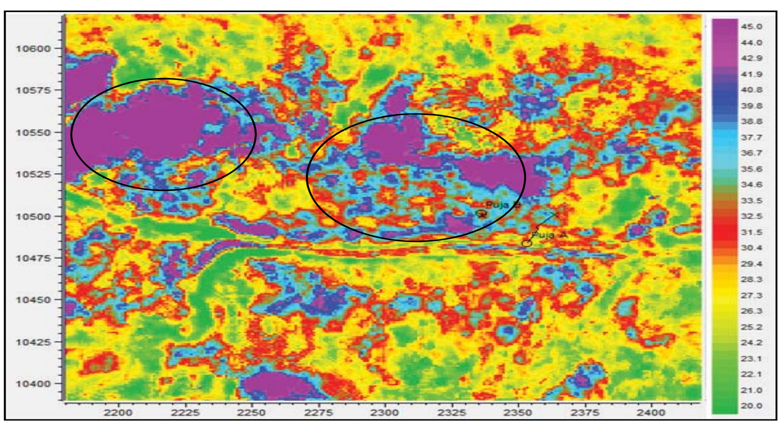
Figure 8
Mu-Rho Which passed Puja A and B wells



(a) Spread map of V_p/V_s



(b) Lambda-Rho spread map



(c) Mu-Rho spread map

Figure 9
Spread maps (a) Vp/Vs (b) Lambda-Rho and (c) Mu-Rho

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