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# 3D Pre-Stack Simultaneous Inversion and Lame Parameter Extraction Applied To Discriminate The Lithology and Pore-Fluid (Case Study: Gumai Formation, Jambi Sub-Basin, South Sumatra)

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**Summary**

The Gumai Formation facies architecture is complex and formed by interbedded sand and shale. The formation has various roles in the Jambi Sub-Basin petroleum system acting as the regional seal, source rock, and reservoir rock. This research was carried out in order to discriminate lithology and detecting pore fluid distribution using Pre-stack Simultaneous Inversion and LambdaMuRho Extraction in the Gumai Formation, Jambi sub-basin which is supported by the proven discoveries of hydrocarbon (gas) while Drill Stem Testing (DST). The data consists of 3D seismic partial-angle stacks and well log data which are used as input to three-term Fatti equation to transform the seismic trace into reflectivity. Further, reflectivity from different angle stacks are simultaneously inverted to obtain P-impedance (Zp), S-Impedance (Zs) and Density (ρ). The simultaneous inversion results for gas bearing sand reservoir encased in shale gave low P-Impedance, low S-Impedance and low density. The Lame parameter extraction, resulted low LambdaRho (Incompressibility) and relatively high MuRho (Rigidity).
Based on these values, combined maps of P-impedance (Zp), S-Impedance (Zs), Density (ρ), LambdaRho (λρ) and MuRho (μρ) show the distribution of the prospective areas for gas bearing sand reservoir towards western part of the study area.

**Introduction**

The Gumai Formation was formed during maximum phase of transgression in the Early Miocene to Middle Miocene, and comprises predominantly deposits of interbedded marine shales, sandstone, and siltstone. The Gumai Formation has various roles in the Jambi sub-basin petroleum system acting as regional seals, source rock, and potential sand reservoir. A stratigraphic chart of Jambi sub-basin is shown in Figure 1. The widespread marine shales of the Gumai Formation act as the regional seal and provides the highest quality seal for the Upper Talang Akar, Batu Raja equivalent and Gumai Formation (Ginger and Fielding, 2005). Additionally, Gumai Formation also plays the role as source rocks where Gumai shales have TOC 0.71-8.00 with a Hydrogen Index (HI) ranging from 34-603, that shows the formation as oil and gas prone (Marpaung et al, 2006). Finally, the Gumai reservoir potential in this area has been proven by the discoveries of hydrocarbon (gas) while drill stem testing (DST).

The difficulty discriminating the lenticular sand bodies and pore fluid in the shaly sand of the Gumai Formation requires quantitative interpretation techniques as reservoir characterization tools that can provide reliable estimates of P-wave velocity, S-wave velocity, density or Poisson's ratio and Lame parameter information. The common goal of these methods is to extract information about lithology, reservoir quality, and pore fluids from pre-stack seismic amplitudes (Chopra & Castagna, 2014) and Goodway et al. (1997) introduced the LambdaMuRho analysis method providing an alternative perspective to the determination of rock fluid properties. Therefore, pre-stack simultaneous inversion dan Lame parameter extraction were chosen to be applied for this study.

**Method**

The datasets used in this study consist of 3D seismic partial angle stacks - divided into three parts, near angle stack ($4^o$-$18^o$), mid angle stack ($18^o$ -$32^o$) and far angle stack ($32^o$-$47^o$), well log data (TR-1, TR-3, TR-4, and TR-6), and horizon interpretation.

The workflow starts with seismic and well log data conditioning prior to the inversion process. Simultaneous Inversion requires wavelet for each angle stacks. In this study, wavelet extraction is performed using statistical wavelet. The second step, shear wave log prediction, is performed because of the limited amount of shear wave data is available (from the 4 wells only 1 well has shear wave information). Shear wave log prediction was performed using Fluid Replacement Modelling (FRM) with reservoir properties as input (saturation water, hydrocarbon saturation, volume clay) and calibrated using TR-3 measured shear wave log. Thirdly, the well ties to the seismic volume to maximize the correlation between measured and synthetic data. Then, initial model was built using low-frequency model, constrained by the horizon, seismic RMS velocity, and partial angle wavelets as the input for the inversion. After that, pre-inversion analysis is conducted to control the quality of the inversion result based on the algorithm to minimize the error between the model and measured data. Then, the pre-stack simultaneous inversion based on three-terms Fatti equation was used to invert the partial angle stacks into P-impedance, S-impedance, and Density. Finally, the result of simultaneous inversion are transformed to extract the Lame parameter (LambdaRho and MuRho).

## Result

The target zone of this study is the sandstone reservoir in Gumai Formation, which has potential hydrocarbon (gas) validated by the Drill Stem Test data (DST) at a depth of 3,274 ft (998 m) – 3,290 ft (1003 m) on the key well TR-1.

The inversion results for the P-Impedance (Zp), S-Impedance (Zs) and density (ρ) on Figure 1 (yellow highlighted) demonstrates a good matching correlation curve between inverted data compared to the well log (measured data). The results are presented in the horizon slice map overlaid within the time structure contour map in the study area. Figure 1. shows the distribution of P-impedance (Zp), where the target zone is interpreted as low impedance with values ranging from 15,700-18,250 (ft/s*gr/cc) or 4,785-5,563 (m/s*gr/cc) which is shown in red to yellow colour and delineated by black strips line.

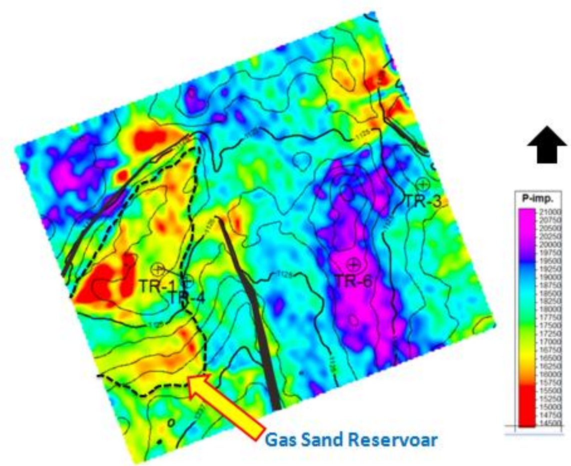


Figure 1: The map distribution of P-impedance inversion result overlaid with time structure map (contour interval is 22.5 ms), which shows low P-impedance value (red to yellow colour) as the gas sand reservoir that delineated by a black strips line in the west direction.

The second inversion result is S-impedance (Zs) shown in Figure 2, where the target zone is interpreted as low impedance with values ranging from 9,078-10,850 (ft/s*gr/cc) or 2,767-3,307 (m/s*gr/cc) which is shown in red to yellow colour and delineated by a black oval. The low impedance value closely relates to rocks with high porosity. The third result is the density (ρ) shown in Figures 2.

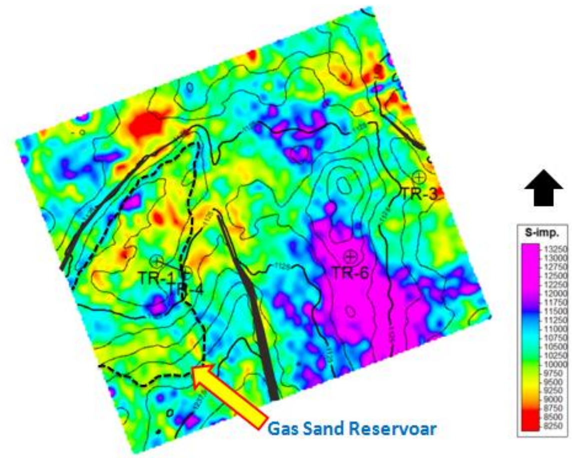


Figure 2: The map distribution of S-impedance inversion result overlaid with time structure map (contour interval is 22.5 ms), which shows low S-impedance value (red to yellow colour) as the gas sand reservoir that delineated by a black strips line in the west direction.

The target zone is identified as low density with the values ranging from 2.10 – 2.19 (gr/cc). This is interpreted as sandstone with a density value lower than surrounding shale. Based on Chopra and Castagna (2014) the density of gas sand reservoir drops more rapidly than oil sand reservoir.

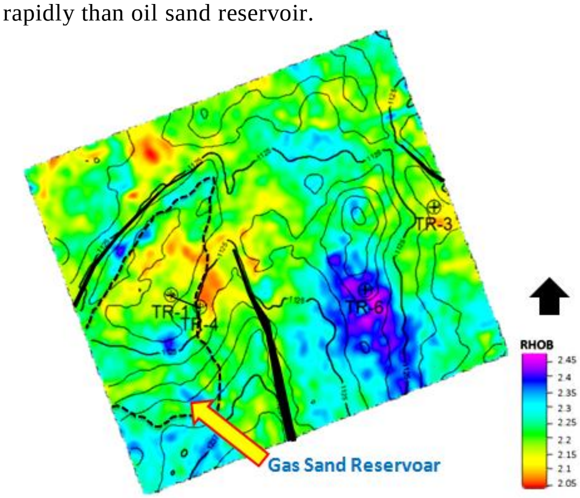


Figure 3: The map distribution of density (ρ) inversion result overlaid with time structure map (contour interval is 22.5 ms), which shown low density value (red to yellow colour). Interpretatation of the gas sandstone reservoir has lower density than surrounding shales, that delineated by a black strips line.

Furthermore, the result of Lame parameter extraction showed LambdaRho (Incompressibility) with low value ranged from 5.05 – 8.6 (GPa*(gr/cc)). The low incompressibility related to the pore-fluid sensitivity, which is gas has high compressibilty (Figure 4). Then, for the MuRho (rigidity) relative high value 9.01-11.3 (GPa*(gr/cc)), which interpreted a gas sand affected by surrounding shale due to the geological condition of Gumai shaly sand (Figure 5).

In addition, the map comparison of the P-Impedance (Zp), S-Impedance (Zs), Density (ρ), LambdaRho (λρ) and MuRho (μρ) showed a good match and interpreted as gas-filled sandstone with the delineation of prospect zone towards the west of study area.

**Conclusion**

The application of pre-stack simultaneous inversion and Lame parameter extraction in Gumai Formation has been proven to discriminate the lithology and pore fluid based on the low P-Impedance (Zp), low shear impedance (Zs), and low density (ρ) which are interpreted as gas-filled sandstones with the distribution of the prospect zone towards the west of study area. These results can be used for further planning of exploration in the Gumai Formation, Jambi Sub-basin, South Sumatra.

**Acknowledgments**

We would like to thank PetroChina International Jabung Ltd., for giving us the permission to publish the data used in this study.

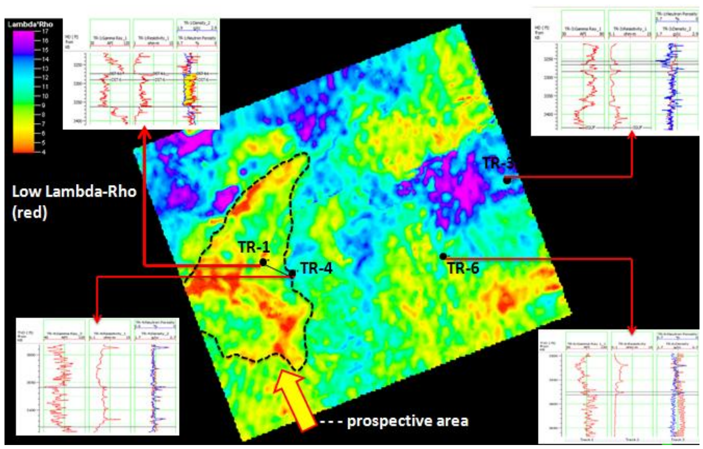


Figure 4: The map distribution of LambdaRho (Incompressibility) , which shows low LambdaRho value (red to yellow colour) as the gas sand reservoir that delineated by a black strips line in the west direction. The four wells trajectories and log parameters (gamma ray, resistivity, density, and neutron porosity) are shown

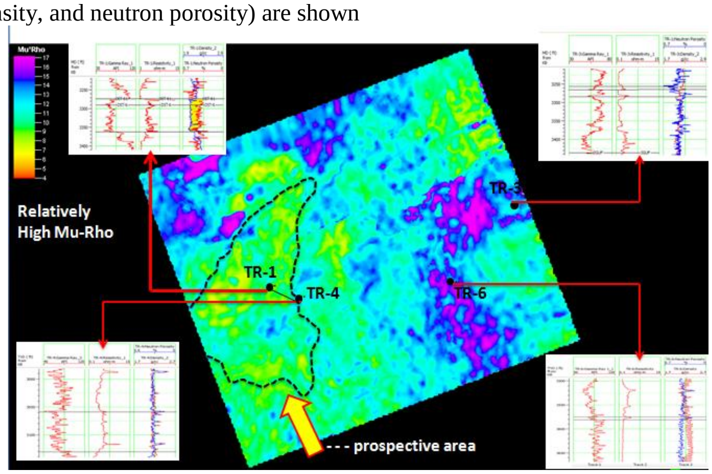


Figure 5: The map distribution of MuRho (Rigidity), which shows low MuRho value (red to yellow colour) as the gas sand reservoir that delineated by a black strips line in the west direction. The four wells trajectories and log parameters (gamma ray, resistivity, density, and neutron porosity) are shown.


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