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Reservoir Characterization using Simultaneous Inversion for Identifying the Sandstone Reservoir of Air Benakat Formation "IDY" Field in South Sumatra Basin

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Abstract. This research was conducted using simultaneous inversion seismic method. The inversion method can be used not only to identify reservoirs, but to identify the fluid content in a rock formation. Formation in this study is Air Benakat Formation, in the South Sumatra Basin. Simultaneous inversion has the results in the form of P-impedance, S-impedance, density, P-wave velocity, S-wave velocity, and v_p/v_s. From the data that have been obtained, that IDY-1 well is considered as a gas saturated sandstone reservoir. Fluid Replacement Modeling (FRM) was also used, in this study, to obtain the detailed information about the presence of gas in the Air Benakat Formation. FRM can simulate the state of the formation if it were in an *in situ* case condition, and in the gas case condition. From the results of FRM processing, that is for the gas case condition of 90%, it was obtained the v_p/v_s value of 1.75 to 1.875. While, in the *in situ* case condition, the ratio was obtained to be 2.0 to 2.2. Based on simultaneous inversion results, the research area is known to have a P-impedance value of 5800 to 6000 (m / s) * (g / cc), an S-impedance of 2000 to 4000 (m / s) * (g /cc), the density of 2.2 to 2.27 $g/g/cm^3$, and the v_p/v_s ratio of 2.17 to 2.25. To identify the distribution of sandstone reservoirs, a horizontal cross-section map was made, which produced results of the cross section of low impedance and low v_p/v_s value. This shows that the IDY-1 well is a well-saturated sandstone reservoir.

1. Introduction

To evaluate oil and gas production, we need methods that can detect subsurface structures, and hydrocarbon content, which may exist. One of the methods is the geophysical method. The most popular geophysical method used in the oil and gas exploration is the seismic method. This method employs the principle of seismic wave propagation under the earth. This study was conducted by using inversion modelling techniques, which is a technique enable to predict some seismic attributes, one of which is the impedance of seismic waves [1].

Body waves consist of P waves and S waves. P waves can propagate in various media such as solid, liquid, and gas medium [2]. S waves, or secondary waves, are seismic waves that only propagate on the surface of the earth [3]. South Sumatra Field has hydrocarbon content in the form of oil and gas [4]. The Air Benakat formation is a formation that has high porosity and permeability because the rock constituent is sandstone. Permeability values can be based on rock sorting, where well sorted have the highest permeability value compared to poor sorted [5].

The South Sumatra Basin is a basin that has an area of 119000 km^2, with a thickness of the average sediment layer of 3.5 km [6]. In the Air Benakat formation, the best sandstone reservoirs generally have a thickness of between 5 and 40 meters which can usually be found in the environment of sea deltas and shallow beaches which are transition zones [7]. Where thickness is based on effective porosity values greater than total

porosity of rocks [8]. This formation is the beginning of regression deposits and consists of layers of beach sand. Its spread is far wider than previous formations and onlapping occurs in Pre-Tertiary rocks to the east on the Sunda Shelf. The sandstone layer here is also an important reservoir layer. The Muara Enim Formation is a swamp deposit as the final phase of regression, and an important coal deposit occurs, such as that found in Bukit Asam [9].

Inversion seismic is the process of calculating subsurface impedance models for seismic data. In other words, inversion uses seismic data to determine subsurface geology. Inversion is the opposite of synthetic seismogram modeling, which uses log data for seismic estimation [10]. Simultaneous inversion is a seismic inversion method using partial stack P wave data which is then inversed to Vp, Vs, Zp, Zs, and density. The pre-stack data concept of the seismic method, if a wave concerning the rock bed boundary will produce an angle value. The coming angle will produce a reflection P wave, a bias P wave and a S reflection wave [11].

2. Methods
The data of this study are 3D full stack seismic data from Post Stack Time Migration (PSTM), and 3D seismic data post stack time migration partial stack. Partial stack data is located near (5 ° -20 °), mid (15 ° -30 °), and far offset (25 ° -40 °), well data, Drill Steam Test data (DST), and top formation data.

3. Result and Discussion
The results in this study are cross-sectional maps of P impedance, S impedance, density, and v_p/v_s. In slicing (Figure 1), the location of the well is indicated by an arrow located at the structural boundary of an anticline, or a delineation well.
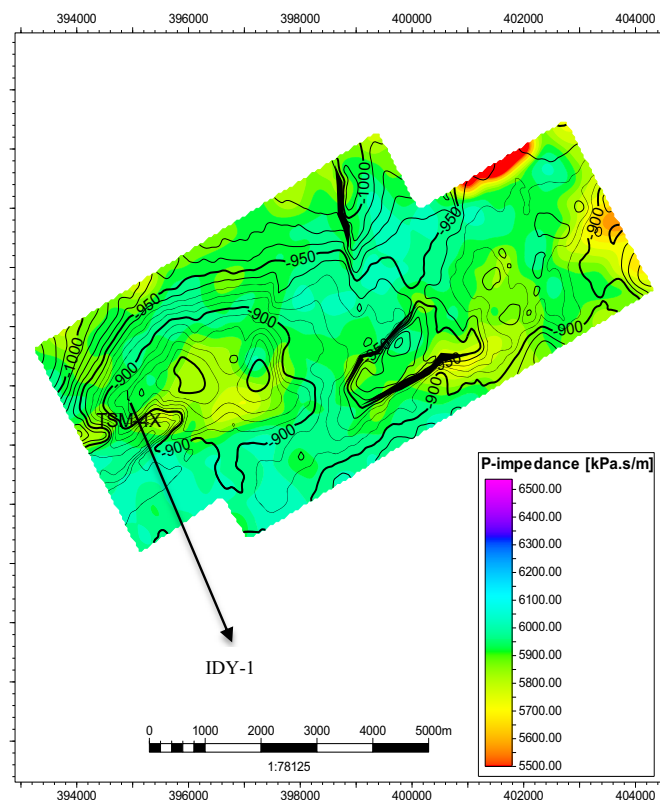

Figure 1. Cross section results from simultaneous inversion of P impedance

In the IDY-1 well the P-impedance value is 5800 to 6000 ((m /s) * (g /cc)), this value is a low impedance but there is a lower impedance value at the top of the anticline ranging from 5700 to 5800 ((m /s) * (g /cc)),

and in the lower regions, near the downward fracture direction northeast which has an impedance value of 5600 to 5800 ((m /s) * (g /cc)) then both regions made as the next recommendation well.

In a horizontal cross section (Figure 2), the location of the IDY-1 well has a uniform value with the other regions being 2000 to 2700 ((m /s) * (g / cc)). There is no low or high anomaly in the S impedance cross section. In recommended well locations, both have a fixed value and change up. This is consistent with the assumption that the area has a gas response and has sandstone lithology.
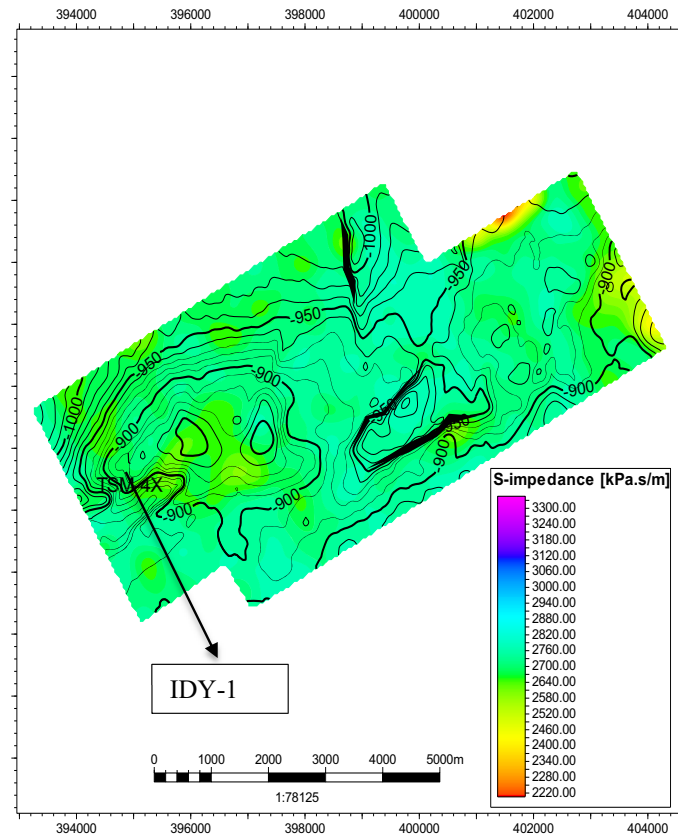

Figure 2. Cross section results from simultaneous inversion of S Impedance

In slicing, which is in Figure 4, the IDY-1 well has a density value of 2.2 to 2.27 g/cm^3. Where 1 cc is equal to 1 cm^3 so the two cross section are of equal value, the difference in the horizontal cross section has a higher accuracy compared to vertical. For recommended wells it has a lower density value than the well IDY-1. Low density values allow rocks to have high porosity and permeability values. Therefore, the placement of recommended wells is more valid.

The horizontal cross section of IDY-1 well (Figure 3) has a low v_p/v_s value of 2.17 to 2.25. This gives information that there is gas in the well. Furthermore, in the two recommended wells it has a lower v_p/v_s value than the IDY-1 well, so the recommended well has a high probability value for the presence of gas.

The results of the overall inversion, the four parameters indicate the similarity of results, the recommended well consists of two wells. The first well is a well located at the top of the anticline while the second well is located in the half and graben fault oriented northeast. The conclusion of the overall inversion is that the IDY-1 well has sandstone formation with gas fluid content. The two recommended wells were named IDY-1X wells and IDY-1Y wells (Figure 5).
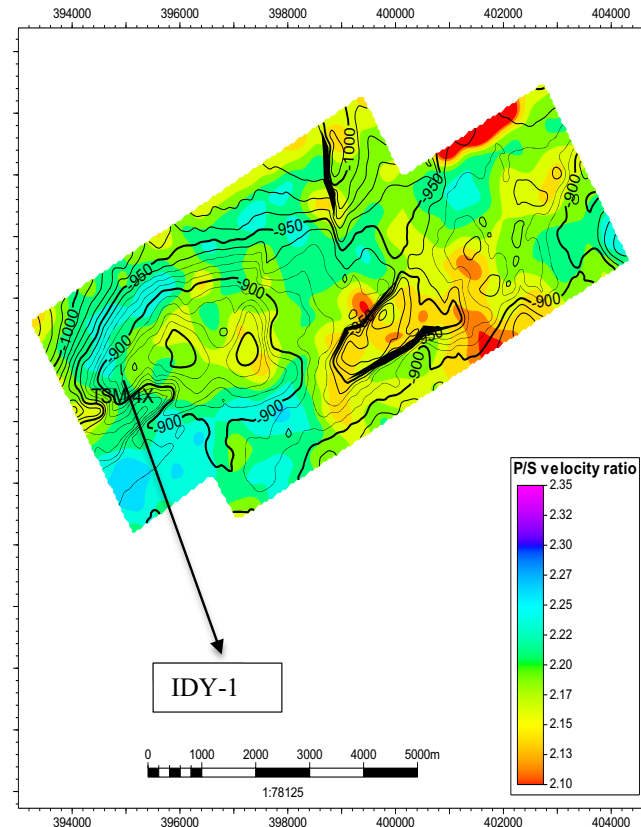
Figure 3. Cross section results from simultaneous inversion Vp / Vs

Figure 6 illustrates the relationship between density and impedance and the legend, v-shale. These three parameters are used to determine lithology in DST-6. But because of the focus of the research on DST-6 so that unnecessary information is not displayed. The v-shale log is a fraction used to determine the presence of clay and sandstone rocks from the gamma ray log response. That is why v-shale can be used to determine the lithology of rock in the research area. The v-shale value is between 0.2 and 0.9. In DST-6 the v-shale value is between 0-0.5, this indicates that DST-6 has sandstone lithology. Whereas the relationship between density and impedance shows a linear relationship. For Acoustic Impedance (AI) DST-6 has a value between 5500-6100 g/cm^3.m / s and a density of 2.1-2.2 g/cm^3. There are also AI values below 4000 g/cm^3.m / s and densities below 1.7 g/cm^3 but have very little data.

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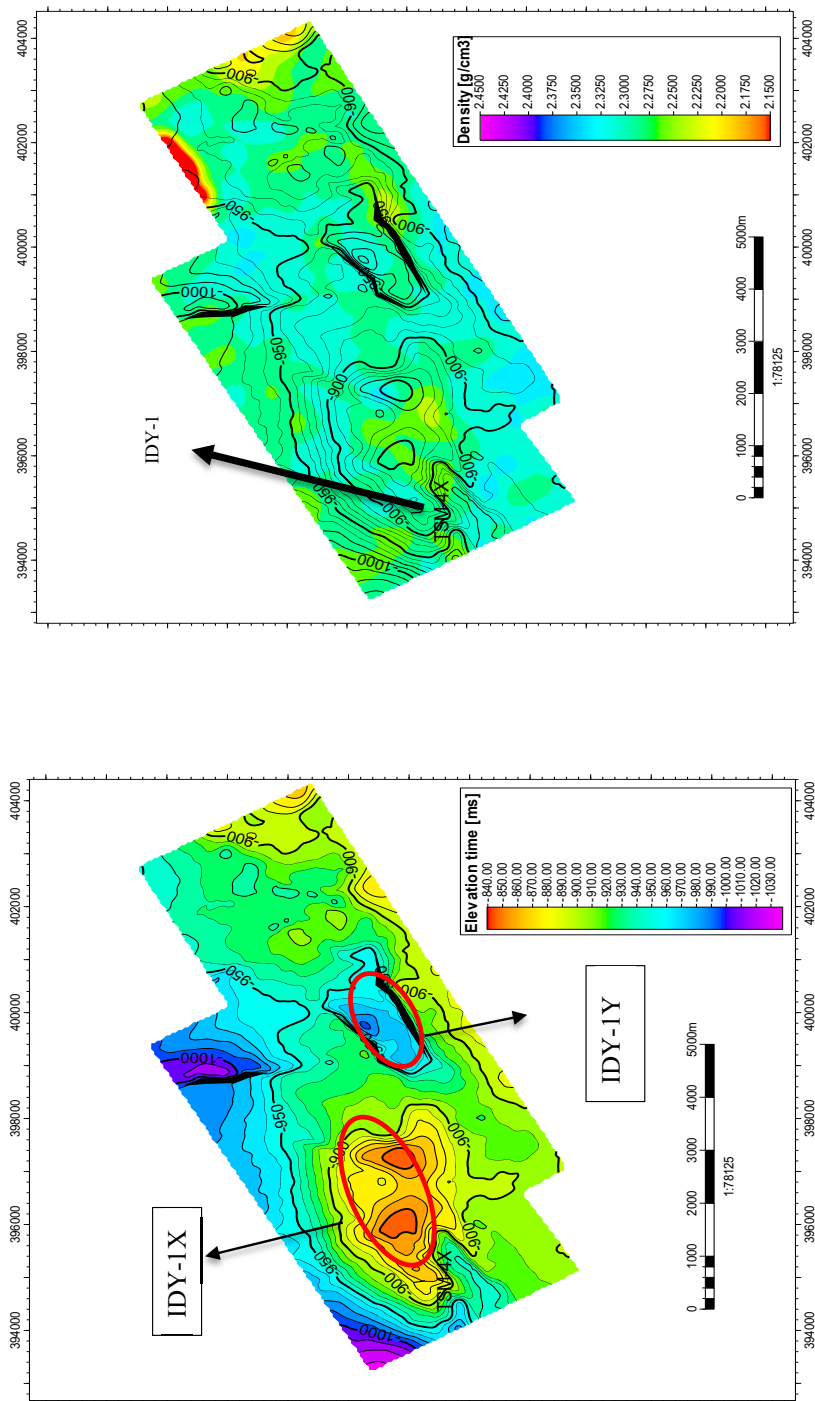
Figure 4. Cross section results from simultaneous inversion by density

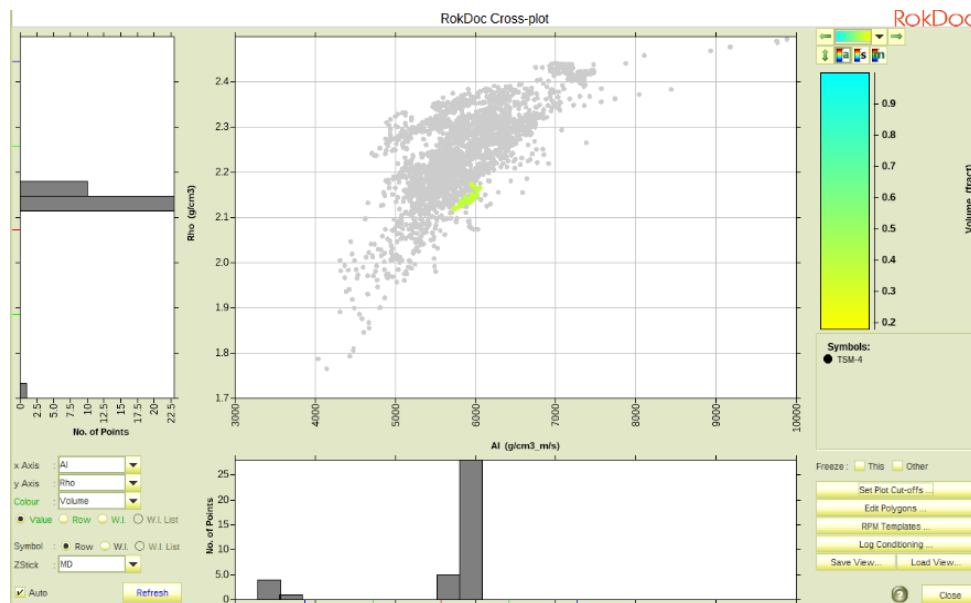**Figure 5.** Location of well recommendations

Figure 6. Relationship between AI and density at DST-6

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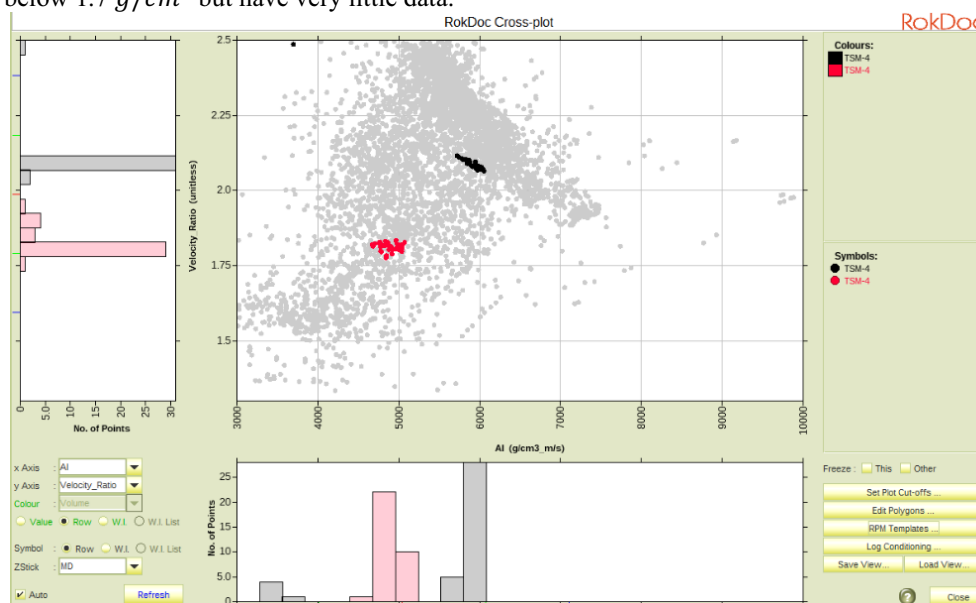

Figure 7. Relationship between AI and velocity ratio at DST-6

Figure 7 is a crossplot between impedance and speed ratio of DST-6. In this graph, displayed two different wells are in situ case condition and gas case condition. This difference is used to compare the AI (impedance) value and speed ratio in in situ conditions and the condition of 90% of gas in the formation.

Legend on the plot, can be identified that black is an in situ condition and red is the condition of 90% of gas in DST-6. In the log in situ, the impedance value of 5500 to 6100 g/cm^3.m /s is obtained. While the value of v_p/v_s in in situ conditions is 2.0 to 2.2. Then, conditions with gas have impedance values and v_p/v_s which are lower than in situ conditions. The condition if there is 90% of gas in the formation has an impedance value of 4500 to 5300 g/cm^3.m / s. Whereas in v_p/v_s the condition of the presence of 90% of gas has a value of 1.75 to 1.875. So, from these two differences in values, it can be concluded that both have different regression trends because of differences in the two conditions.

4. Conclusion

From the study that we conducted, we conclude that the simultaneous inversion methods have indicated the existence of the sandstone reservoir zones, which are characterized by P impedance values and low S impedance, low density, and low v_p/v_s. The hydrocarbons in this formation of the area DST-6, which is part of the Air Benakat formation, are gas. The target position which is suspected to contain hydrocarbons is in the depth range of 840-850 meters. The impedance value of the IDY-1 well, which is 5800 to 6000 ((m / s) * (g / cc)), has a low value. The S impedance value is 2000 to 2700 ((m / s) * (g / cc)), while the density is 2.2 to 2.27 g/cm^3, and, for v_p/v_s , the value is 2.17 to 2.25. The four parameters of the inversion identify that the type of IDY-1 well is gas-saturated sandstone

References
[1]   Price, David George. 2009. Engineering Geology: Principles and Practice. Berlin: Springer
[2]   Afnimar. 2009. Seismologi : Edisi Pertama. Bandung: Laboratorium Seismologi Institut Teknologi Bandung
[3]   Shearer, M. 2009. Introduction to Seismology. Second Edition. New York: Cambrige University press.
[4]   Aina, Zahratul. 2017. Karakterisasi Reservoir Dengan Menggunakan Inversi Simultan Dan Analisis Lambda-Mu-Rho Untuk Mengidentifikasi Persebaran Zona Potensial Reservoir Karbonat Formasi Baturaja Lapangan "Sukses" Cekungan Sumatra Selatan. Sarjana Thesis. Universitas Brawijaya.
[5]   Bear, J. 1972. Dynamics of Fluids in Porous Media. New York: Dover Publications.
[6]   Blake. 1989. The Geological Regional and Tectonic of South Sumatera Basins. Proceeding Indonesia Petroleum Association 11th Annual Convention.
[7]   Ginger, D., K. Fielding. 2005. The Petroleum Systems and Future Potential of the South Sumatra Basin. IPA05-G-039.
[8]   Glover, Paul. 2007. Petrophysics MSc course notes.
[9]   Koesoemadinata. 1980. Geologi Minyak dan Gas Bumi: Jilid 1 Edisi Kedua. Bandung: Penerbit ITB
[10] Hampson, D, Russel, H. 2005. Simultaneous Inversion of Pre-stack Seismik Data. Hampson–Russel Software Service Ltd, and Brad Bankhead. Veritas DGC. SEG/Houston.
[11] Hampson, D. dan Russel, B.H. 2004. AVO Theory. Hampson-Russel Software Services Ltd.