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Pore Pressure Estimation Using Bowers Methods in Shale Gas Reservoir Jambi Sub-Basin

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ABSTRACT

Pore pressure prediction has important implications in determining the success of a drilling activity. Information of subsurface pore pressure prediction in hydrocarbon exploration and production is very important. For geologist this information can be used to determine of hydrocarbon generation and maturation within a basin, while for petroleum engineer pore pressure prediction is very important to maintain the production rate and for drilling engineer this information is useful for mud weigh and casing designs prior drilling activities to prevent blow out. This study is conducted in the well A and B, Field "X", Jambi Sub-Basin. Wells A and B have problems when drilling operations are carried out, such as blow out and pipe sticking which causes high non-productive time (NPT). So, optimum pore pressure prediction analysis must be carried out to avoid downhole problems in the implementation of further development well drilling. First, this study identifies the mechanism of overpressure formation, then predicts pore pressure using the Bowers method and subsequently performs modeling of subsurface 3D pore pressure. The results of the analysis showed that overpressure occurred in the Gumai and Talang Akar Formations, overpressure mechanism in the formation was caused by compaction, fluid expansion (kerogen maturation), and based on analysis of 3D pore pressure modeling many overpressure zones were found in the Gumai Formation, Jambi Sub-Basin.

Keyword : Pore Pressure; Bowers Methods

ABSTRAK

Prediksi tekanan pori memiliki implikasi penting dalam menentukan keberhasilan suatu kegiatan pemboran. Informasi prediksi tekanan pori bawah permukaan dalam eksplorasi dan produksi hidrokarbon sangat penting. Untuk ahli geologi informasi ini dapat digunakan untuk menentukan pembangkitan dan pematangan hidrokarbon di dalam cekungan, sedangkan untuk ahli perminyakan prediksi tekanan pori sangat penting untuk mempertahankan laju produksi dan untuk insinyur pemboran informasi ini berguna untuk penimbangan lumpur dan desain selubung sebelum kegiatan pemboran. untuk mencegah ledakan. Penelitian ini dilakukan di sumur A dan B, Lapangan “X”, Sub-Cekungan Jambi. Sumur A dan B mengalami kendala pada saat operasi pemboran dilakukan, seperti blow out dan pipe sticking yang menyebabkan tingginya waktu tidak produktif (NPT). Oleh karena itu, analisis tekanan pori tekanan pori yang optimal harus dilakukan untuk menghindari masalah downhole dalam pelaksanaan pemboran sumur pengembangan lebih lanjut. Pertama, penelitian ini mengidentifikasi mekanisme pembentukan overpressure, kemudian memprediksi tekanan pori menggunakan metode Bowers dan selanjutnya melakukan pemodelan tekanan pori 3D bawah permukaan. Hasil analisis menunjukkan bahwa overpressure terjadi pada Formasi Gumai dan Talang Akar, mekanisme overpressure pada formasi disebabkan oleh pemadatan, ekspansi fluida (maturasi kerogen), dan berdasarkan analisis pemodelan 3D pore pressure banyak ditemukan zona overpressure pada Formasi Gumai, Sub Cekungan Jambi.

Kata Kunci: Tekanan Pori; Metode Bower

1. Introduction

The identification and prediction of the pore pressure of a formation largely determines the success of the drilling process, according to pore pressures hold a percentage of 27% in the success of drilling, followed by stability of the hole drill by 17% [1]. Therefore, the prediction and analysis of good pore pressure is absolutely necessary to optimize the drilling process such as casing design planning, estimation of mud weight, and drilling disaster mitigation due to overpressure zones, and can reduce costs in the drilling operation itself. The subsurface pressure analysis is carried out to determine the mud weight optimum that is used to maintain the stability of the borehole which is influenced by the voltage around it. During the drilling operation carried out on the "X" Field, drilling problems that often occur are often found in wells A and B, with various drilling problems, namely Kick and Pipe sticking. This problem can be avoided by analyzing subsurface pressure so that drilling with NPT can be achieved to a minimum and ultimately can optimize the exploitation of hydrocarbon reserves [2]. Pore pressure prediction using the Bowers method is better than the Eaton method because it can predict high pore pressure values and the Bower method is considered more capable of predicting the optimal mud weight value for drilling at that depth.

The South Sumatra Basin consists of five sub-basins namely the Jambi Sub-Basin, North Palembang Sub-Basin, Central Palembang Sub-Basin, South Palembang Sub-Basin, and Bandar Jaya Sub-Basin. The location of the study on the X field located in the Jambi sub-basin [3]. The South Sumatra Basin regional stratigraphy is shown in Figure 1. From the old to the young are Basement, Lahat Formation, Talang Akar Formation, Baturaja Formation, Gumai Formation, Air Benakat Formation, Muara Enim Formation, and Kasai Formation. Focus of this study is the Talang Akar Formation. This formation is dominated by sandstone at the bottom and claystone at the top. It is deposited incongruously above the Lahat Formation that divided into 2 members, namely GRM (grit sand member) which is composed of rough clastic with shale inserts and coal, and TRM (transitional members) which is composed shale. The deposition environment of the Talang Akar Formation is in the littoral to the shallow marine environment, which is in the late Oligocene - Early Miocene. The thickness of the formation varies between 100 - 500 meters. The contact between the Talang Akar Formation and Telisa and the Telisa Limestone Basal members is conformable. The contact between Talang Akar and Telisa is difficult to pick from wells in the trough area because the lithology of these two formations is generally the same.

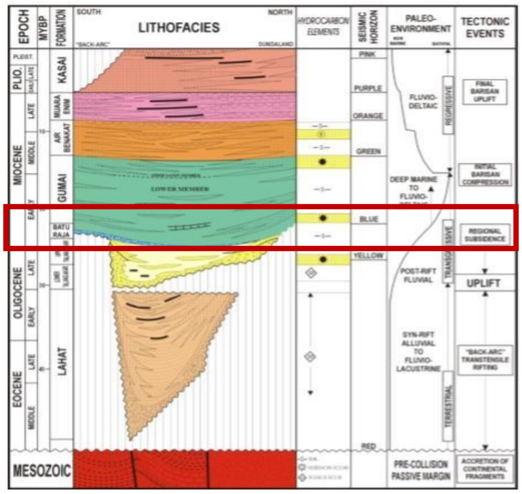


Figure 1. Stratigraphy of the South Sumatra Basin [3].

2. Basic Theory

2.1. Geopressure

Hydrostatic pressure or normal fluid pressure is the pressure exerted by a static column of water of the same height as the overlying pore fluids and the same density as the pore water. Pore pressure is (fluid pressure or formation pressure) is the pressure exerted by the pore fluids. Overpressure is the excess pressure above normal pressure. Overburden pressure (lithostatic pressure or geostatic pressure) is the pressure exerted by the overlying pore fluid and rocks. Fracture pressure is the total of the pressure that the formation can hold before a formation damaged and destroyed [4].

2.2. Overpressure Formation Mechanism

The mechanism of overpressure can be caused by two mechanisms, namely the mechanism relating to loading and a mechanism that not related to the process of loading (unloading). The mechanism of loading is related to overburden pressure due to the sedimentation process that takes place faster than normal conditions. This rapid sedimentation process causes the fluid inside the rock pore to not be able to get out and be trapped during the burial. Consequently, the pore pressure in the rock increases and the sediment in a compact failure/disequilibrium compaction condition. The unloading mechanism occurs due to an increase in the mass of fluid inside the rock pore. Overpressure formed through this mechanism is characterized by a reduction in the effective stress value of rocks [5]. Based on the cross plot between density and velocity to detect the mechanism of overpressure which is described by Hoesni that in the blue plot shows the density increases, the velocity increases too. It shows the mechanism of overpressure that caused by disequilibrium/normal compaction. Brown plot reveal at certain densities with a constant value, velocity has drastic decreased as depth increasing as well. This explains the mechanism of overpressure caused by fluid expansion. The green plot shows that the density increases but the velocity decreases which indicates that the overpressure mechanism is caused by a hybrid chemical. The last, the red plot explains that the velocity is constant and the density increases which indicates that the mechanism of overpressure is caused by chemical compaction/clay diagnosis [6].

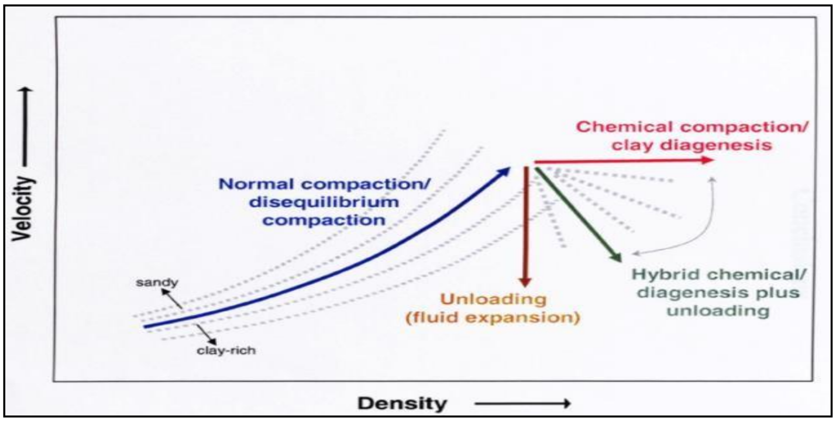


Figure 2. Pattern of cross-plot density with velocity to detect overpressure mechanisms [6].

2.3. Pore Pressure Prediction Bowers Method

The Bowers method basically uses a concept similar to the Eaton method, which is an equation to determine the Effective Stress value. However, the equation expressed by Bower is better than Eaton because the Bower equation more considers the unloading factor. Therefore, the Bower method more suitable for predicting formations that have high pore pressure values with loading and unloading mechanism. The Bower method to predict pore pressure is introduced by Bower as [7]:

$$V = 5000 + A\sigma^{B} \quad (1)$$

$$V = 5000 + A\left[\sigma_{max}\left(\frac{\sigma}{\sigma_{max}}\right)^{\frac{1}{U}}\right]^{B} \quad (2)$$

$$\sigma_{max} = \left(\frac{V_{max} - 5000}{A}\right)^{\frac{1}{B}} \quad (3)$$

where:
V = Velocity (Ft /s),
σ = Effective pressure (Psi),
σ_{max} = Maximum effective pressure (Psi),
A and B = Bower empirical coefficient

2.4. Seismic Inversion

Seismic inversion is a technique to create subsurface geological models using seismic data as input and well data as controls [8]. After performing a seismic inversion, an acoustic impedance cross section can be produced. Acoustic impedance is the ability of a rock to pass through an acoustic wave. The acoustic impedance value is empirically formulated as:

$$AI = \rho V_p \quad (4)$$

where:
AI = acoustic impedance (kg/m^2.s),
ρ = density (kg/m^3),
V_p = velocity (m/s).

Acoustic impedance values are influenced by lithology, porosity, fluid content, depth, pressure, and temperature.

3. Methodology

The methodology in determining the overpressure mechanism using cross plot density vs. velocity and depth vs. Rho plot. Pore pressure determination using the Bowers method and seismic data used to map the distribution of estimated pore pressure using trend velocity vs. pore pressure obtained from well data. From the map, we can determine the condition of pore pressure at a certain depth according to the geological structure in the zone.

4. Results and Discussion

4.1. Analysis of the Causes of Field X Overpressure

4.1.1. Well A. The analysis of the overpressure mechanism using cross plot sonic log and density log (Hoesni plot) in well A (see Figure 3) shows that the mechanism of overpressure in well A is caused by undercompaction and fluid expansion. The figure shows the velocity and density at a depth of 4400-4800 ft increases but at 4800 ft-5200 ft the velocity and density decrease.

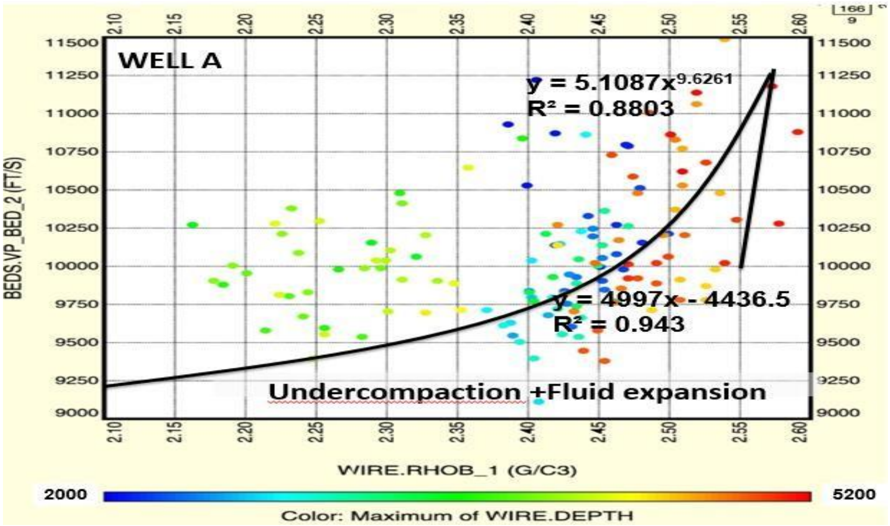


Figure 3. Cross plot between *V*p and density in well A using Hoesni plot.

In well A, depth vs. Ro analysis was also performed, shown in Figure 4. The top oil window is at a depth of 4429.35 ft in the Talang Akar Formation. High temperatures make kerogen in this rocks formation turn into hydrocarbons. This shows that if there is a mature hydrocarbon below, it is likely that if the mass addition of the pore fluid results from changes in the solid matrix to a fluid (oil fluid), so that the pressure rises when there is no fluid coming out of a system that causes increased pressure on the rock pores.

From the results of cross plot sonic log analysis and density log using Hoesni plot and depth vs. Ro, the mechanism of overpressure in well A is caused by undercompaction and fluid expansion due to the release of hydrocarbons by kerogen. The difference mechanism seems occurred to the different formations. The Gumai Formation experienced an overpressure mechanism of undercompaction whereas the Talang Akar Formation experienced an overpressure mechanism of fluid expansion due to the release of hydrocarbons by kerogen.

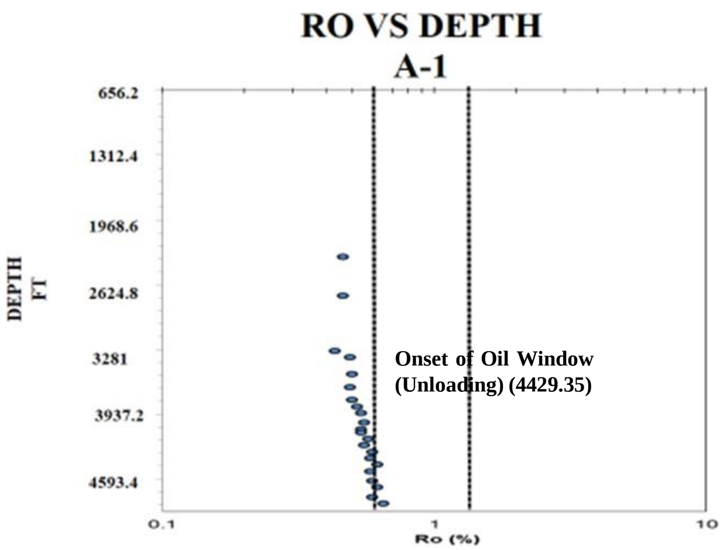


Figure 4. Plot Depth vs. Ro of well A.

4.1.2. Well B. Analysis of the overpressure mechanism using cross plot sonic log analysis and density log (Hoesni plot) in B well shown in Figure **5.** It found that the mechanism of overpressure in well B is caused by both undercompation and fluid expansion. The cross plot result shows the velocity and density at a depth of 4200-5800 ft increases but at a depth of 5800 ft-6200 ft the velocity and density decrease. The analysis of the overpressure mechanism in well B only uses crossplot velocity and density because there are no reports of depth vs. Ro data.

From the results of crossplot shows that the mechanism of overpressure in well B looks likely caused by both undercompaction and fluid expansion. The Gumai Formation experienced an overpressure mechanism of undercompaction whereas the Talang Akar Formation experienced an overpressure mechanism of fluid expansion.

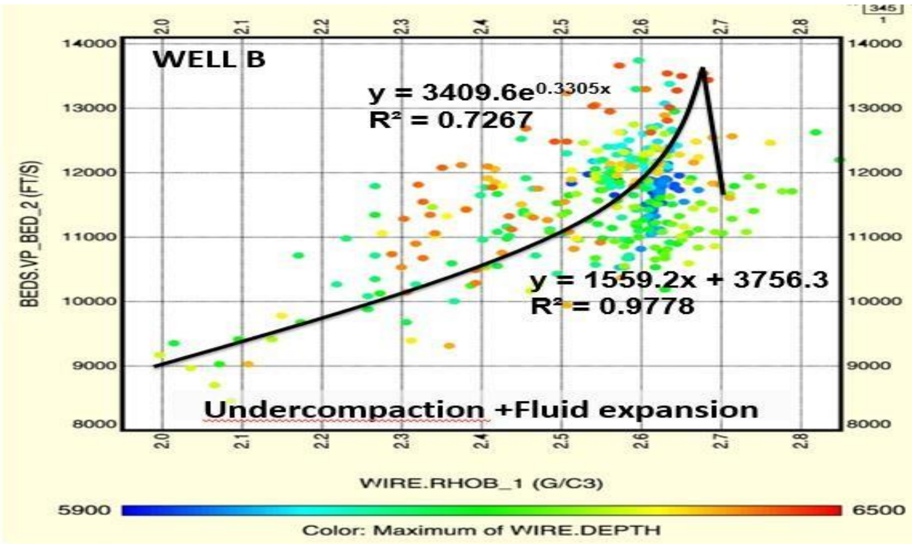
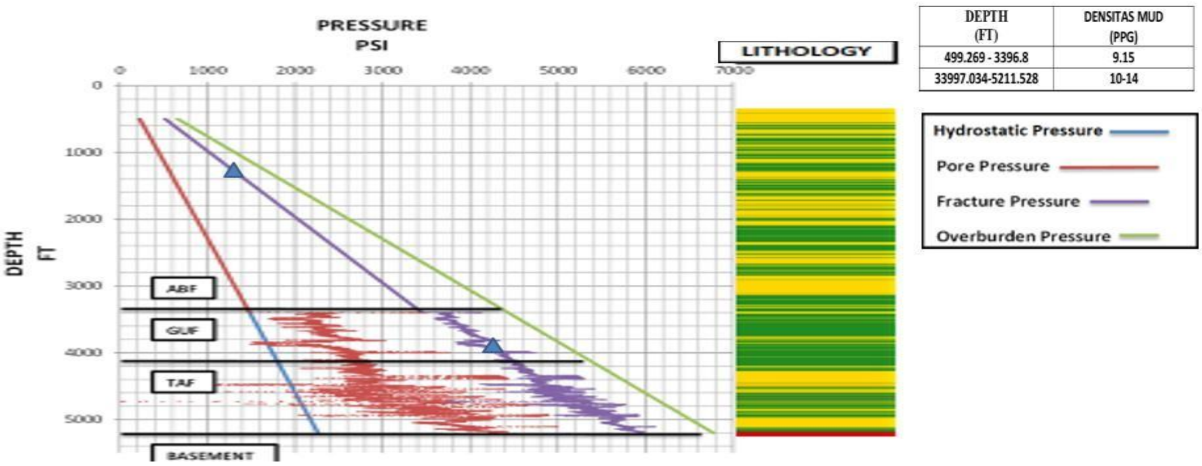


Figure 5. Cross plot between *V*p and density in well B using Hoesni plot.

4.2. Pore Pressure Analysis of Calculation Results

4.2.1. Well A. Pore pressure estimation carried out in well A using the Bowers method identified the presence of hydrostatic pressure at a depth of 499,269 ft-3396.8 ft and an overpressure zone at a depth of 3300 ft-5100 ft. The Bower empirical coefficient on the calculation of pore pressure well A estimation is A = 15.8, B = 8.9, and coefficient of unloading is U = 3.5. Estimated hydrostatic pressure is calculated uses a hydrostatic pressure gradient of 0.433 psi/ft and for overburden pressure using an overburden pressure gradient of 1.01 psi/ft. Furthermore, the calculation of fracture pressure uses the Eaton method. Figure 6 shows the pressure profile in well A.

Therefore, a good density of mud used at a depth of 800 ft-3300 ft is 9.15 ppg, while at a depth of 3397 ft-5100 ft is 10-14 ppg. In well A does not have a pressure test data so it cannot calibrate its porous pressure model.

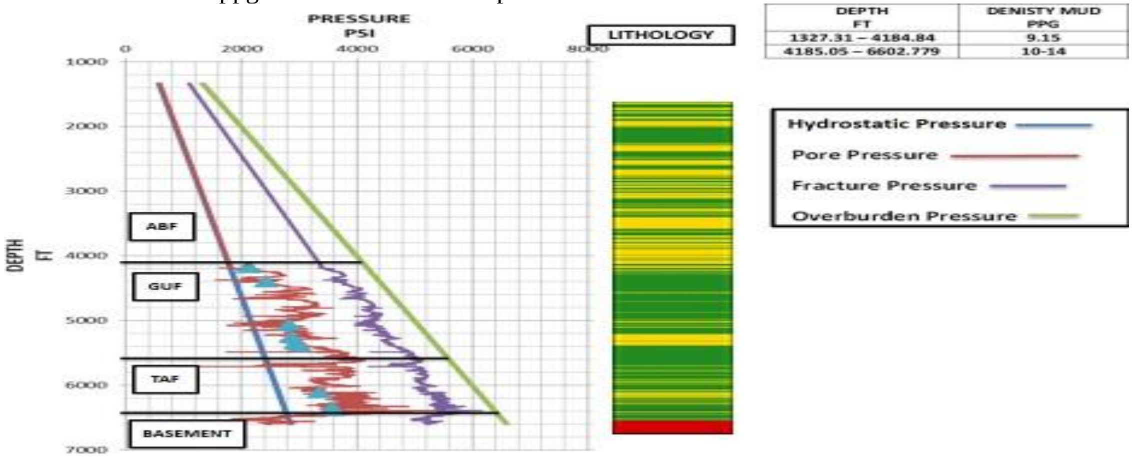


DEPTH (FT)	DENSITAS MUD (PPG)
499.269 - 3396.8	9.15
33997.034-5211.528	10-14

Figure 6. Pore pressure profile in well A.

4.2.2. Well B. The pore pressure estimation carried out in well B using the Bowers method identified the presence of hydrostatic pressure at a depth of 1327.31 ft-4184.84 ft and an overpressure zone at a depth of 4100 ft - 6600 ft. The Bower empirical coefficient on the calculation of well B pore pressure is A = 15.8, B = 8.9, and coefficient of unloading is U = 3.5. The estimated hydrostatic pressure which is calculated uses a hydrostatic pressure gradient is 0.433 psi/ft and for overburden pressure using an overburden pressure gradient of 1.01 psi/ft. Furthermore, the calculation of fracture pressure uses the Eaton method where the pressure profile in well B is shown in Figure 7.

Therefore, a good density mud used at a depth of 1327 ft-4184 ft is 9.15 ppg, while at a depth of 4185 ft-6600 ft is 10-14 ppg. The results of the pore pressure model used are calibrated with a pressure test so that the model is made close to the bottom pressure actual surface.



DEPTH FT	DENISTY MUD PPG
1327.31 – 4184.84	9.15
4185.05 – 6602.779	10-14

Figure 7. Pore Pressure Profile in well B.

4.3. Pore Pressure Modeling Analysis

Distribution of pore pressure estimation uses trend velocity vs. pore pressure obtained from well data with calibration pore pressure well data. A velocity model map is made to show the distribution of velocity values laterally which is inversely proportional to the pore pressure value from the crossplot velocity to pore pressure.

The Gumai Formation shows a low-moderate pore pressure value. At the bottom of the formation it is known that a shale layer is dominated but there are not many overpressure points in this layer (Figure 8). In the Talang Akar Formation the value of pore pressure is medium-rather high value. Yellow thin layers show a rather high pore pressure values. The formation contains quite a lot of shale so that many overpressure points are detected in this formation layer (see Figure 9). The Talang Akar Formation detected many high overpressure points because in this formation there was a change in rock diagenesis (kerogen maturation) in the analysis of the overpressure mechanism. Red colour represents the highest pore pressure value, yellow and green represent moderate pore pressure values between red and blue, while blue represents the lowest pore pressure value. Visible colour contrast limiting layer patterns indicates that in different formations, the distributed pore pressure value is also different. At the bottom of Talang Akar Formation the value of pore pressure shows a very large value, regardless of the formation of the target which is the most in high pressure as well.

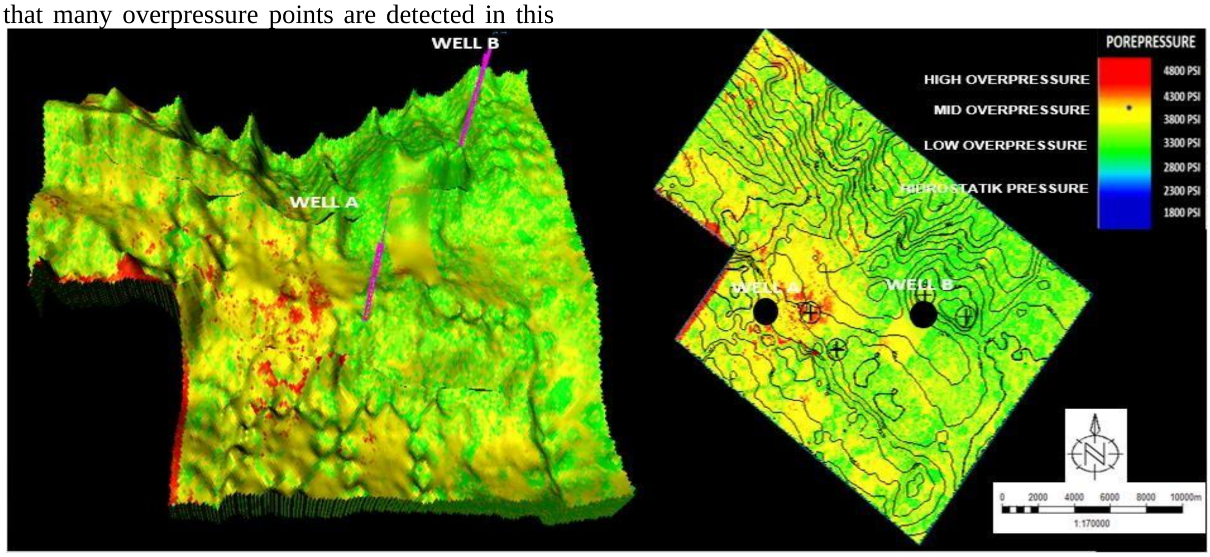


Figure 8. 3D Model of Pore Pressure at Gumai Formation.

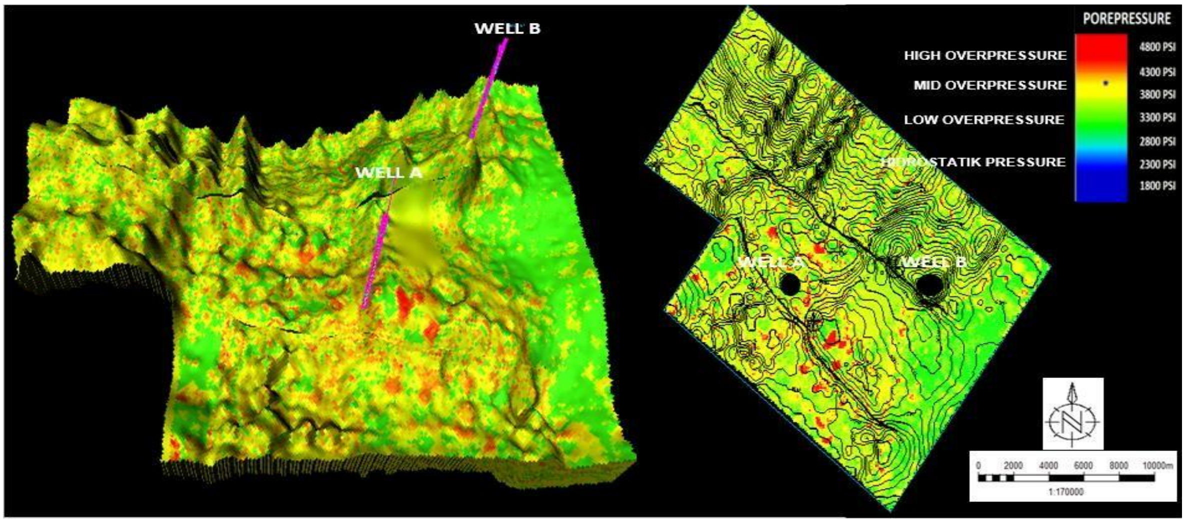


Figure 9. 3D Model of Pore Pressure at Talang Akar Formation.

5. Conclusion

Based on data processing, analysis, and interpretation that has been done in this study, it can be concluded several things, namely:

1. The results of the analysis of calculation of pore pressure using the Bowers method in wells A and B indicate that top overpressure occurs in the Gumai Formation.
2. The mechanism of overpressure that occurs at X Field is caused by both undercompaction and fluid expansion (kerogen maturation).
3. The 3D pore pressure model is able to predict pore pressure for planning the weight of drilling mud.
4. The Talang Akar Formation are shale rocks so the type of mud that recommended to be used is oil based mud (OBM).

Acknowledgement

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