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Overpressure's top and generating mechanism in "APR" block, North Sumatra offshore area

A Pradana[1*]**, J Setyowiyoto**[1]**, B Prasetyo**[2] **and W Haidar**[2]

[1]Geological Engineering Department, Universitas Gadjah Mada
[2]Pertamina Hulu Energi North Sumatra Offshore
[*]E-mail: pradana.aryapradana.arya@gmail.com

Abstract. The offshore North Sumatra Basin is one of the hydrocarbon-prone basins in Indonesia. The Malacca Formation acts as the reservoir in this basin. However, there are some drilling problems caused by abnormal pore pressures. Overpressure analysis is carried out so that drilling activities are avoided from drilling problems such as kicks, blowouts, stuck pipes, loss circulation, and collapse. This study aims to analyze the overpressure in the "APR" block, offshore North Sumatra Basin, which includes determine the depth of the top overpressure and the mechanism of overpressure formation. In the research area, analysis of 3 exploration wells was carried out. Overpressure is analyzed based on well log data, and pressure test data using the Eaton method (1975) supported by other data such as LOT (Leak-Off Test) data, drilling reports, mudlogs. At Well A, top overpressure depth is ± 3235 ft TVDSS (true vertical depth sub sea). At Well P, top overpressure depth is ± 3065 ft TVDSS, and at Well R, top overpressure depth is ± 2901 ft TVDML (true vertical depth mud line). The overpressure generating mechanism in the study area is caused by the loading mechanism (disequilibrium compaction) and caused by the nonloading mechanism (hydrocarbon buoyancy).

1. Introduction

The North Sumatra Offshore area is a well-known productive basin in Indonesia. Several exploration wells at the "APR" Block had encounter drilling problems due to overpressure condition on the area. However, the characteristics of the overpressure, which includes top of overpressure on the area and generating mechanisms related to its geological environment, is still unknown.

This research uses three wells data at the "APR" Block, which will be analyzed to find the top of overpressure (Figure 1). It is highly important to know the characteristics because overpressure give heavy consequences in oil and gas industry, especially in drilling problems such as kick, blowout, and loss circulations. Therefore, overpressure analysis are important before drilling projects can be started at the research area.

Figure 1. Research area shown within the red square.

2. Geological Setting

North Sumatra Offshore area belongs to the North Sumatra Basin, and located at the offshore southern side of Mergui Basin [3]. Physiographically speaking, the area is one of the back-arc basins in Indonesia and formed by the subduction of Indian Ocean Plate and Eurasian Plate [2]. Figure 2a shows Sumatra's regional geology map, and Figure 2b shows the vertical section of the North Sumatra Basin.

Structurally, none of any major fault or other kind of structures was found. Stratigraphic column [1] is shown on Figure 3 shows the target area of the overpressure analysis which includes Seurula Formation, Keutapang Formation, and Malacca Formation.

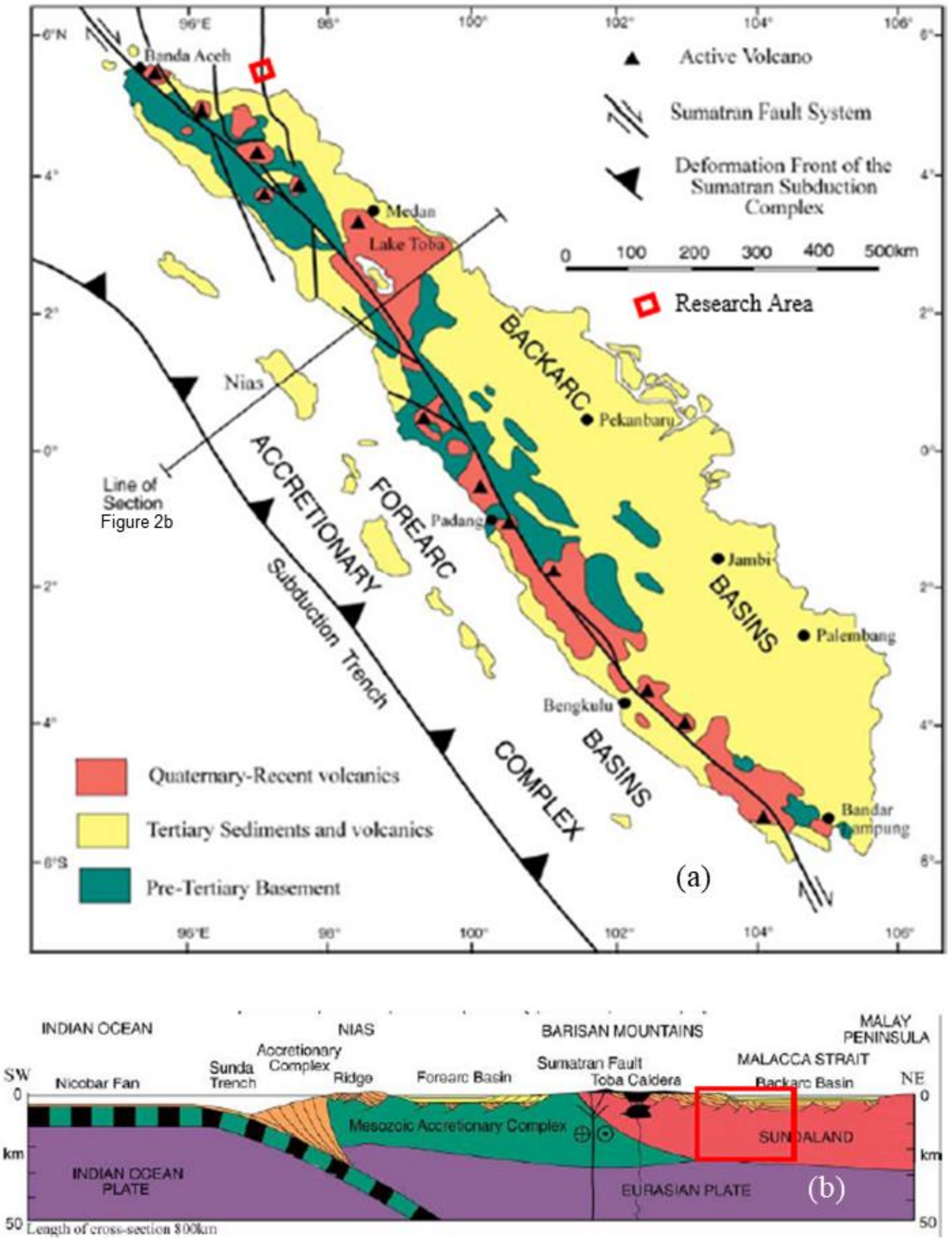

Figure 2. (a) Geologic Map of Sumatra [2], shows the distribution of stratigraphic and volcanism units. Research area shown by the red box. (b) Vertical section of the Sumatra's subduction system.

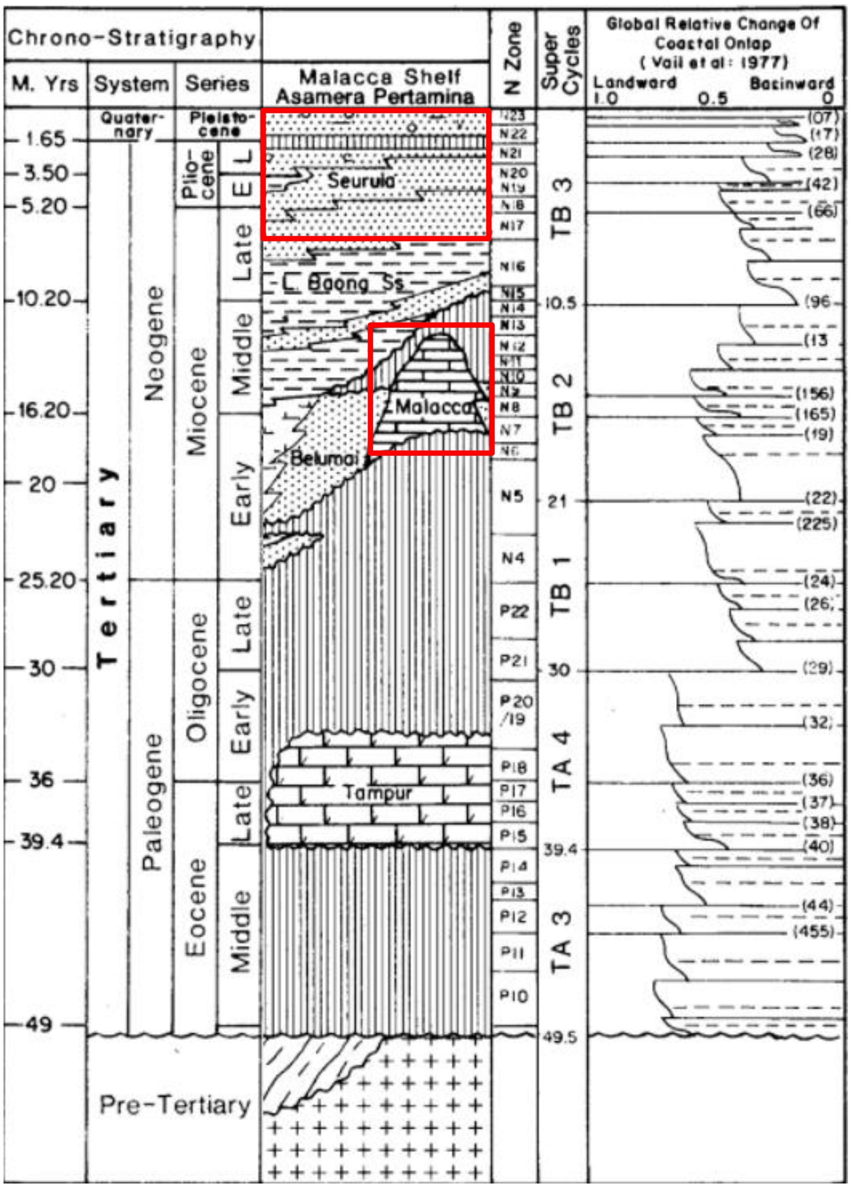

Figure 3. Stratigraphic column of North Sumatra Offshore [1]. Research formations shown by the red box.

3. Methods

This research uses wireline logs, direct pressure data, mudweights, drilling events, and leak-off test to identify the top of overpressure at each wells. Those data are presented as pressure-depth profile. Then, the profiles will be analized to determine top of overpressure and its generating mechanism.

Mudweight could be an indicator for the detection of overpressure, marked with the addition of mudweight. Drilling event i.e kick, loss, blow out, pull/drag, hole fill, connection gas, etc, may be caused by overpressure. Another data that we use to anlyze overpressure in this research is wireline log data.

The hydrostatic pressure is calculated using the default value of fresh water density gradient, and the lithostatic pressure is calculated using the wireline log data, which is the density log [5]. For the pore pressure calculation, the wireline log data processing will be conducted at first by discriminate between sand-rich and shalerich value from the shale volume value. After that, the sonic/vp log or the resistivity log on the shale intervals is used to create the normal compaction trend (NCT) and also to calculate the pore pressure value using Eaton's equation. Fracture pressure calculation is also done, with the leak-off test data and the pore pressure calculation itself [5].

The responses of wireline log data will show two basic types of overpressure generating mechanisms, which are loading and unloading [4]. Loading mechanism response will show constant trend of logs, caused by the dewatering rate is lower than the sedimentation rate, made the fluid couldn't escaped from the pore space (Figure 4a). Meanwhile, unloading mechanism will show reflecting pattern of log response from normal compaction trend, due to fluid expansion, made the pore space getting larger than before (Figure 4b). Aside from both loading and unloading mechanism, there are also another mechanism (nonloading mechanism) such as hydrocarbon buoyancy, aquathermal pressuring, hydraulic head, and osmosis. Those mechanism have their own characteristic of overpressuring from the pressure profile, for example the pore pressure profile from the hydrocarbon buoyancy's overpressure can be shown at Figure 4c.

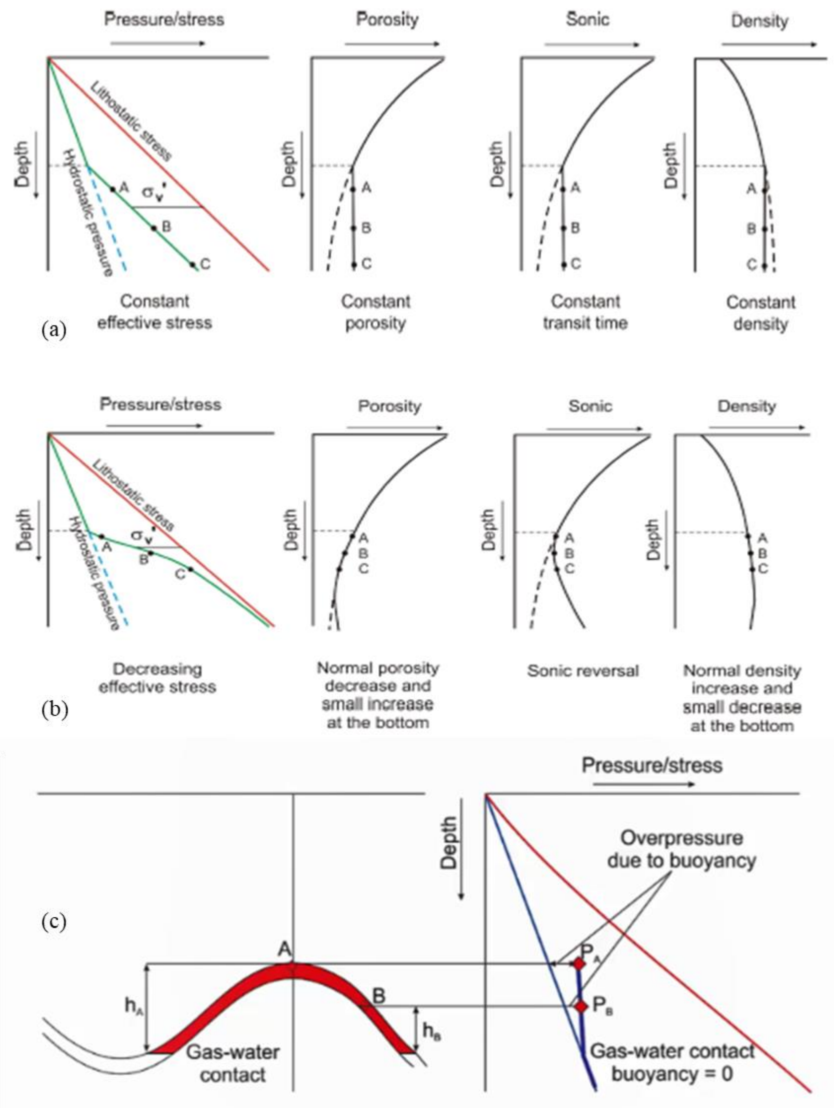

Figure 4. (a) Pressure-depth profile and wireline log response to loading mechanism. (b) Pressure-depth profile and wireline log response to unloading mechanism. (c) Example of pressure-depth profile to hydrocarbon buoyancy overpressuring.

4. Top of Overpressure Analysis

4.1. A-Well

At the A-well, the top of overpressure is at 3235 ft TVDSS, which is located in Keutapang Formation (Figure 5a). Top of overpressure is determined when the sonic log is deflecting from the normal compaction trend. From the gamma ray log, it shows decreasing value of shale volume, interpreted as decrease of the rock matrix percentage due to presence of the fluid. From the density and neutron logs, it also shows deflection from the NCT's (Figure 5b). There are also a drilling events which is well kick and increase at mud weight value. Increase of mud weight is happened due to increase of pore pressure value. The direct pressure measurement (which is Drill Stem Test) is also calculating the same value with the pore pressure prediction from vp log.

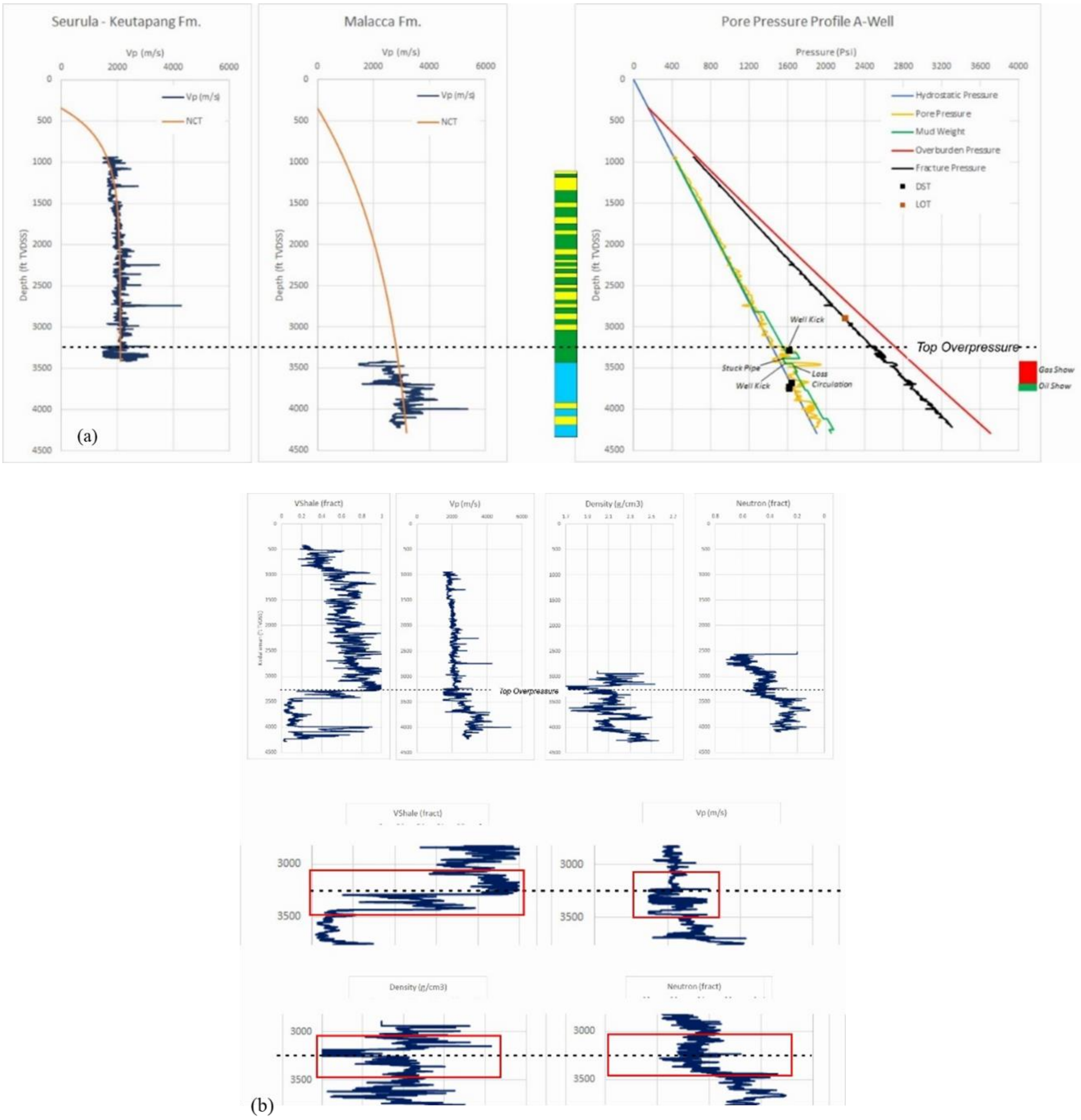

Figure 5. (a) Pore pressure profile of A-Well. (b) Wireline log responses of A-Well.

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4.2. P-Well

At the P-well, the top of overpressure is at 3065 ft TVDSS, which is located in Malacca Formation (Figure 6a). Top of overpressure is determined when the sonic log is deflecting from the normal compaction trend. From the gamma ray log, it shows a significant decrease value of shale volume, interpreted as difference of lithology. From the density and neutron logs, it also shows deflection from the NCT's, even though there is no porosity log data at previous interval (Figure 6b). There are some lacks of wireline log data in this well at several intervals. These lacks made the overpressure analysis couldn't been done perfectly.

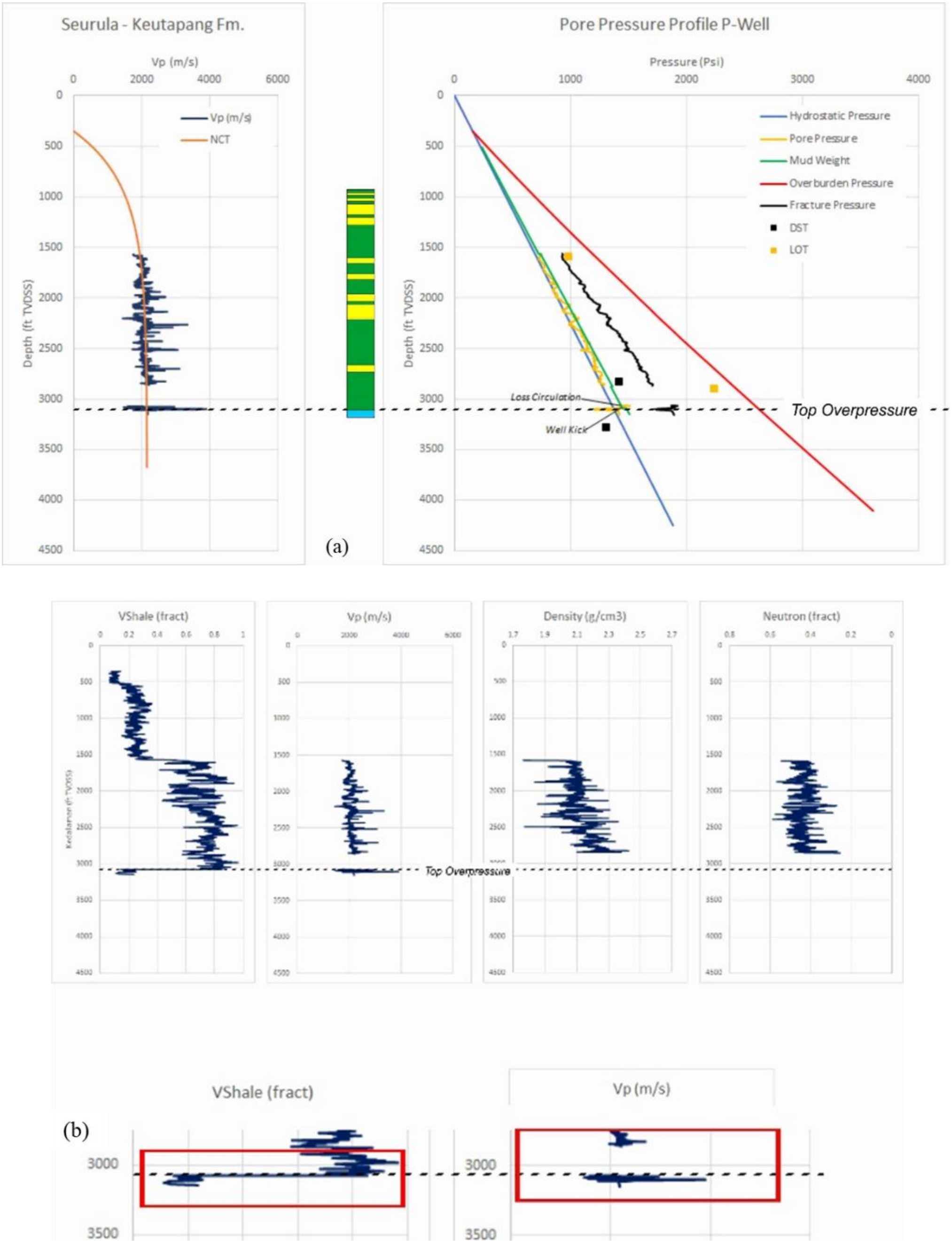

Figure 6. (a) Pore pressure profile of P-Well. (b) Wireline log responses of P-Well.

4.3. R-Well

At the P-well, the top of overpressure is at 2901 ft TVDML, which is approximately located in Keutapang Formation (Figure 7a). Top of overpressure is determined when the resistivity log is deflecting from the normal compaction trend. From the gamma ray log, it shows high value of shale volume, interpreted as high shale content (Figure 7b). None of the density and porosity logs are available in this depth. This lack made the overpressure analysis couldn't had been done perfectly. Also, there are no available information regarding to the mud weight and any direct pressure measurements, so the calculation couldn't be validated.

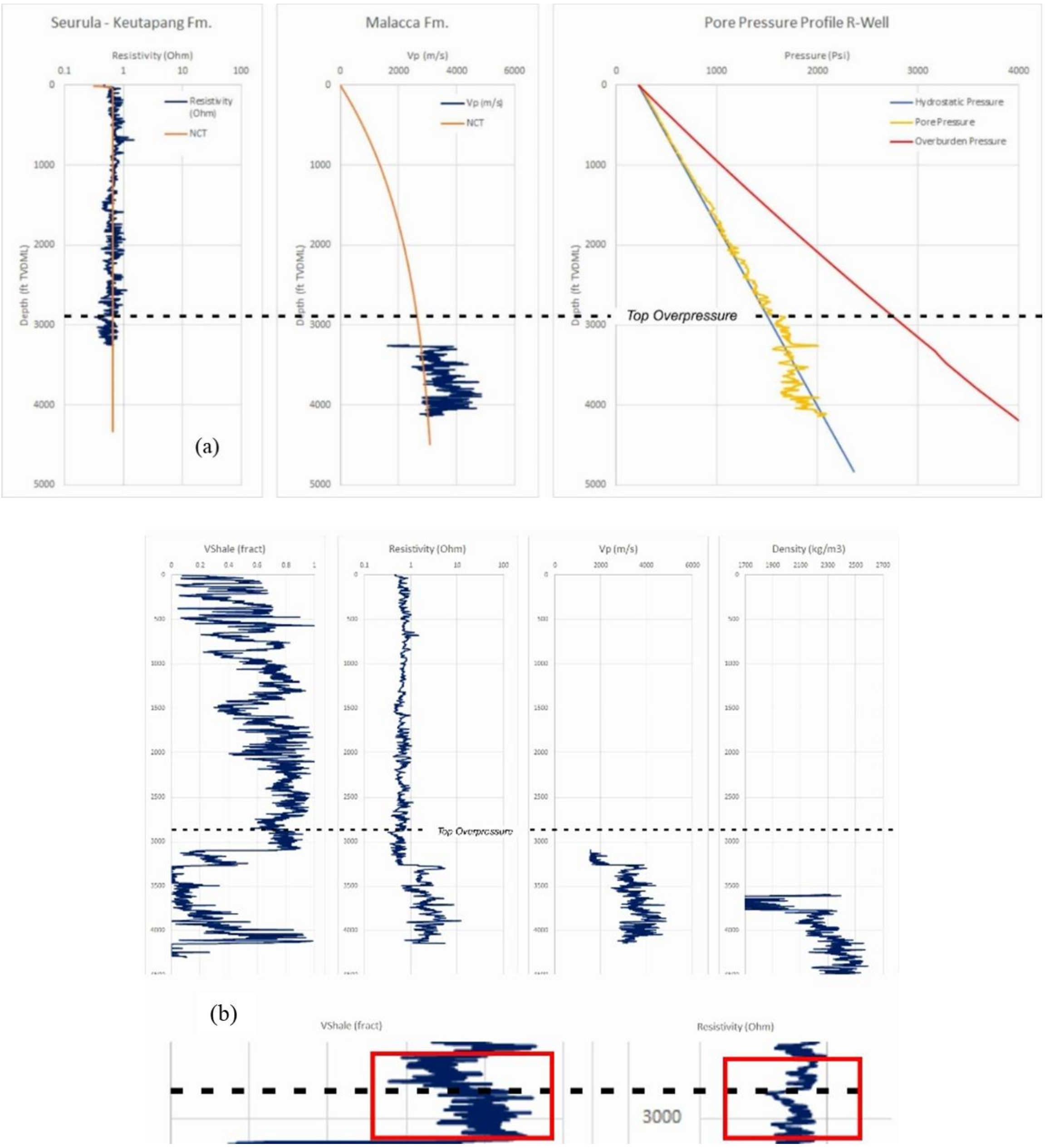

Figure 7. (a) Pore pressure profile of R-Well. (b) Wireline log responses of R-Well.

5. Overpressure Generating Mechanism Analysis

5.1. A-Well

Pore pressure profile shows a loading mechanism (disequilibrium compaction) response at 3235 ft TVDSS – 3435 ft TVDSS (Figure 8). This mechanism happened due to the undercompacted shale that decrease the dewatering rate, so the water would be trapped and increased the pore pressure (overpressure). Other intervals which are 3435 ft TVDSS – 3783 ft TVDSS, there is an increase of pore pressure in different lithology (carbonate). That interval is interpreted as the nonloading mechanism (hydrocarbon buoyancy). From the mudlog data, it is confirmed that the carbonate interval's act as hydrocarbon reservoir, which the overpressure is generated from the hydrocarbon column buoyancy.

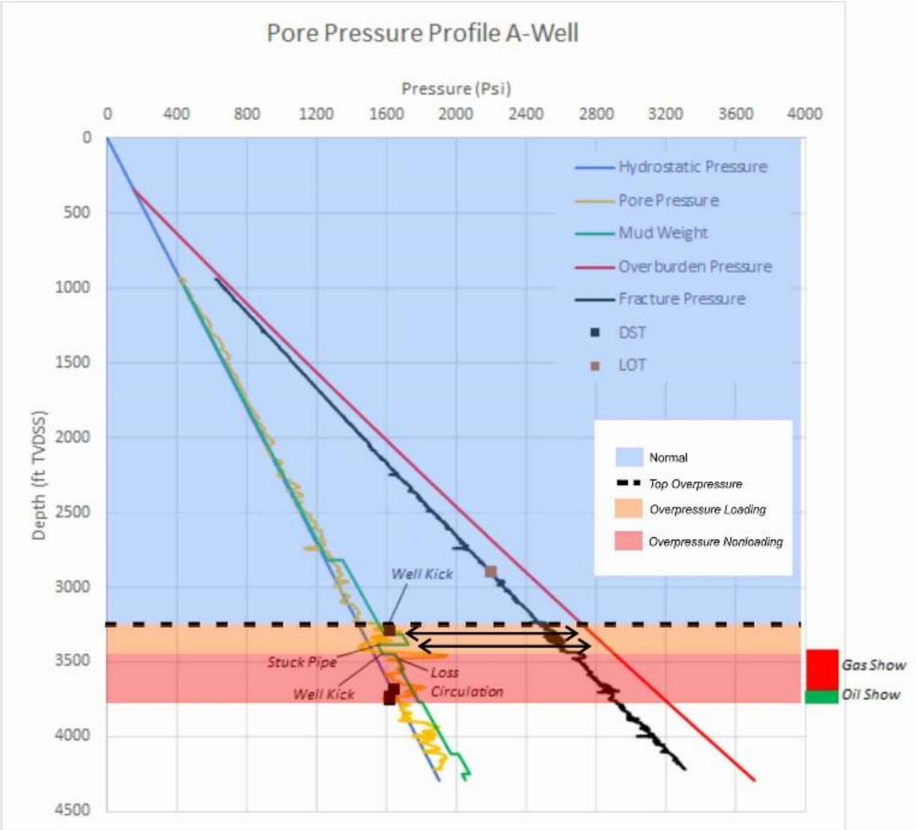

Figure 8. Pore pressure profile of A-Well and its overpressure generating mechanism.

5.2. P-Well

Pore pressure profile shows a nonloading mechanism (hydrocarbon buoyancy) response at 3065 ft TVDSS – final depth (Figure 9). This mechanism happened due to the presence of hydrocarbon, that has the buoyancy factor. Even though the mudlog did not have the cutting's data at the certain depth, but the resistivity log shows a high value, which can be one of the indicators of the presence from the hydrocarbon.

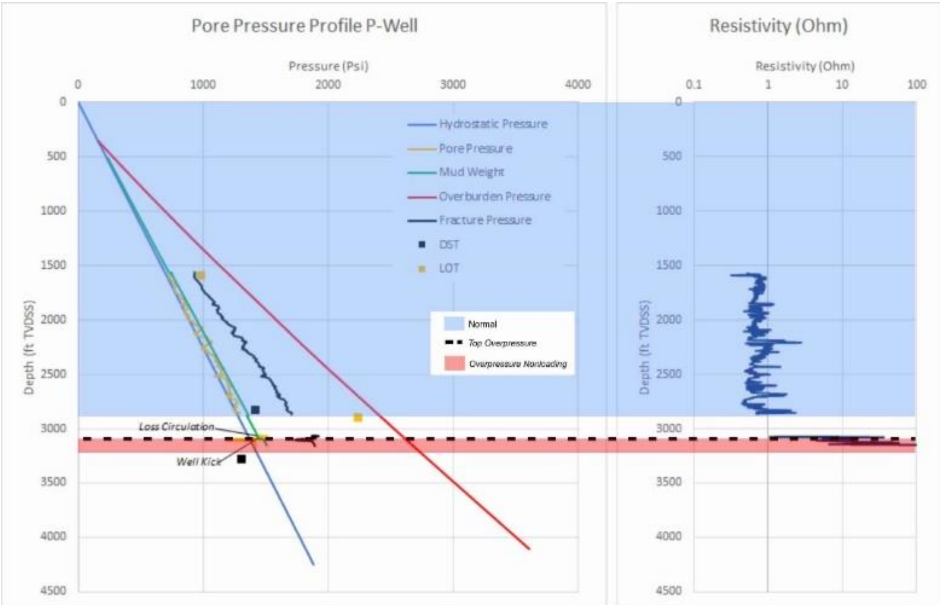

Figure 9. Pore pressure profile of P-Well and its overpressure generating mechanism. At nonloading mechanism zone, resistivity log shows higher value, indicating the hydrocarbon presence.

5.3. R-Well

Pore pressure profile shows a loading mechanism (disequilibrium compaction) response at 2901 ft TVDML – 3275 ft TVDML (Figure 10). Same as A-Well, this mechanism happened due to the undercompacted shale. Apart from the overpressure condition, there are also an underpressure condition which is marked with the pore pressure value that less than the hydrostatic. Regardless of the final data report unavailability, the underpressure condition was found in carbonate section (probably Malacca Formation), which shown by the low gamma ray value.

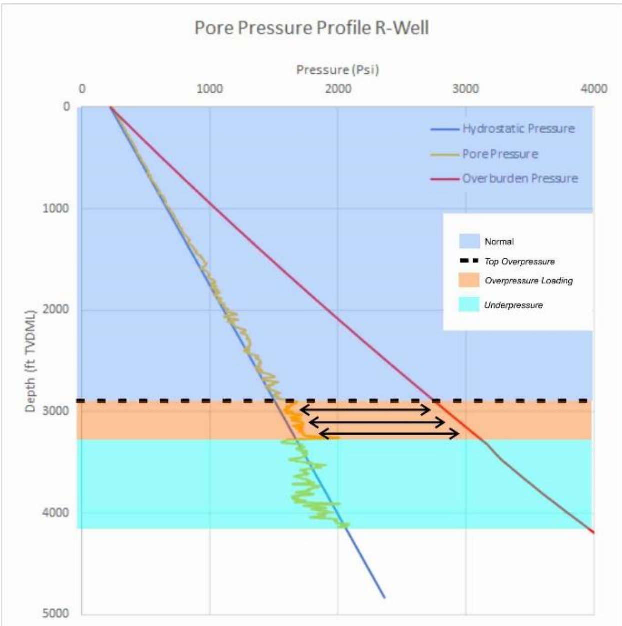

Figure 10. Pore pressure profile of R-Well and its overpressure generating mechanism. There is also an underpressure zone in this well.

6. Conclusion

At the "APR" Block, the overpressure occurrence is associated with shale lithology and presence of hydrocarbon. Tops of overpressure are detected by the wireline log data, at shale dominated sequence (A-Well and R-Well) or at the reservoir zone (P-Well). Overpressure generating mechanism analysis shows that the overpressure at the research area was generated by several mechanism, which are loading mechanism (disequilibrium compaction) and nonloading mechanism (hydrocarbon buoyancy).

Acknowledgments

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