Analysis on the overpressure characterization with respect to depositional environment facies: Case Study in Miri Area, Baram Delta.

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Abstract. Overpressure studies in oil and gas exploration and production are carried out in order to mitigate any losses that could happen while drilling. These concerns can be addressed by enhancing the understanding of overpressure characterization in the fields. This research emphasizes in determining the pore pressure trend in Miri area to assist pore pressure prediction for future hydrocarbon exploration and production. Generally, pore pressure trends are related to mechanisms that contribute to the overpressure generation. In the region predominant overpressure are disequilibrium compaction within the prodelta shales meanwhile in outer shelf overpressure generation controlled by fluid expansion in deltaic sequence of inner shelf area. The objective of this research is to analyze the pore pressure profile of wells for determining vertical trends of pore pressure for various depositional environment facies of Miri area. Integration of rock physics and pore pressure analysis and relating the trends to environment depositional environment facies within shale underlying sand interval. Analysis done shows that overpressure top is characterize by depositional environment facies within shale underlying sand interval.

Keywords: Overpressure, Overpressure mechanism, Depositional environment facies

1. INTRODUCTION

The Miri area located in the South China Sea in between Kalimantan and Brunei. Miri area is known to be one field of the Sarawak Basin and petroleum in Sarawak is produced from Neogene rocks that occur mostly in the offshore areas of Sarawak Basin [6]. Some authors claimed that the Sarawak Basin continue westwards into Indonesia as the East Natuna Basin and is separated from the Sabah Basin to the east by a major tectonic discontinuity called the West Baram Line as a major transform fault [2]. Evidence shows that this fault has significantly influenced the sedimentary evolution of the NW Borneo margin, as separating evolution of the carbonate sedimentation (Central Luconia Province) from deltaic siliclastic sedimentation (Baram Delta Province) [8].

In this study, field-scale distribution of overpressure trend is conducted in Miri area and basic analysis of pore pressure characteristic is demonstrated as a first step in pore-pressure estimation. The research choose Miri area as the study area due to some concern which is uncertain distribution overpressure mechanism in Miri area. The research suggest to investigate the origin of overpressure mechanism generated in Miri area. So, the study comply the understanding on relationship between the trends of
pore pressure profile with the environment of deposition. Other concern of the study is due to under prediction of high overpressure buildup by seismic velocities in Miri area is one of the concern in this study. Thus, the study try to provide the essential foundation for subsequent vertical and lateral overpressure trend useful for pore pressure estimation.

2. LITERATURE REVIEW

2.1 Geological Setting

The location of these study area is in the Northeastern part of Sarawak, Malaysia. The project site are at two wells known as MA-3 and MA-5. MA-3 is located proximal to the shelf area of Baram Delta meanwhile MA-5 is distal from the shelf area with the distance of two well is around 50km apart as shown in Figure 1.

![Figure 1: A map of location of Baram Delta and the well location of MA-3 (purple circle) and MA-5 (green circle) in the Miri area. Modified from (Peter, Derek & Robert, 2015).](image)

2.2 Pore pressure Mechanism

The overpressure mechanism in Miri area is caused by two different mechanisms which are disequilibrium compaction and fluid expansion. The behaviour of widespread occurrence of overpressure have strong correlation between the disequilibrium compaction and fluid expansion. Disequilibrium compaction or under compaction is commonly described as the main contribution to overpressure generation in Baram Delta, it was driven by the rapid sedimentation underneath the prograding delta [14]. Other factors that control the high overpressure accumulation is in inner shelf of deltaic sequence overpressure being generated by any conventional fluid expansion mechanism (kerogen-to-gas-maturation) and was proposed that these overpressures have been vertically transfer into reservoir unit via faults, from prodelta shales [13].
3. METHODOLOGY

![Diagram showing methodology of research study]

**Figure 2: The methodology of this research study.**

The study focuses on the offshore of Miri area to emphasize on understanding and predicting of overpressure zone using the well log motif approach. This study stressed on the rock physics analysis resulting on the trends of overpressure in the study area. The research began with overview structural, sequence and rock physics analysis on well data from the Miri area. Subsequently, well log analysis done for environment depositional facies studies. Significant cross plots were created in order to analyze the pore pressure trend. Further analysis was conducted on the pore pressure analysis for the well located in the Miri area. Pore pressure analysis was conducted to see the trend of porosity and density log from its normal compaction trend in Miri area. The report on the pore pressure trend that comprise of all the significant analysis produced at the end of the research. Thus, the resulted to the trend of pore pressure profile respected to overburden pressure as well as environment of deposition.

4. RESULT AND ANALYSIS

4.1 Pore pressure profile

Pore pressure is the essential parameters for physical properties and for geomechanical and geological analyses. Pore pressure is defined as fluid pressure in the pore spaces in the porous formation. Hydrostatic (normal) pressure is associated with a column of water from surface to depth of interest. Lithostatic pressure occurs when the pore pressure exceeds the hydrostatic values in a confined pore volume at depth.

Right profile in Figure 3 shows the variation of pore pressure from MA-3 with depth in Miri area. Top overpressure begin at depth 2960m. The transition overpressure zone present at 2960-3040m. At the depth of 3040m the hard overpressure shows a sharp change in pressure with depth until reach 3110m. Deep overpressure is recognise at depth of 3110m until it reach the highest pore pressure at depth 3212m. Left profile in Figure 3 shows the variation of pore pressure from MA-5 with depth in Miri area. Top of overpressure begin at depth of 2090m. Transition overpressure zone present at 2090-2140m is increase gradually with depth. Hard overpressure present at depth 2140m shows sharp change in pressure with depth until it reach 2468m. Deep overpressure is recognise at depth of 2468m until it reach the highest pore pressure at depth 2786m.
Figure 3: Pore pressure profile of MA-3 and MA-5. Hydrostatic gradient represent in green line (9.84 MPa/km) and lithostatic pressure represent in red line (20.36 MPa/km). Pore pressure profile of MA-5. Hydrostatic gradient represent in green line (10.52 MPa/km) and lithostatic pressure represent in red line (20.36 MPa/km).

Focusing on the location of the well, MA-3 is located in inner shelf and MA-5 is located in outer shelf. Based on previous studies, researchers believe that both well are controlled by different overpressure mechanism either disequilibrium compaction or fluid expansion. Even though, both well are located 50km apart but they actually shows the same trend of pore pressure which is pore pressure shows the gradual changes in depth. Identical of pore pressure trend between two well means there are some similarities present in the zone that lead to deviation of the overpressure generation in the well at certain depth. This might be due to the matching lithology and structural style of the well. By having integration of lithology and structural style with the trend of pore pressure studies can improve the overpressure prediction of the wells for other oil and gas fields.

4.2 Facies characterization

Sequence stratigraphic shows the geometry of the sediment change by depth and each well experience different sequence stratigraphic. So, identifying log motif is important for recognizing the depositional environment of the well. Log motif is useful for the depositional environment analysis of the well located in Miri area. Facies characterization is necessary in order to distinguish the trend of the overpressure in the different sand packages. It give us better correlation that show the depositional environment could respond to the pore pressure trend in Miri area. Besides, it enhances the visualization of pore pressure variation on that particular depth interval. Firstly, facies characterization done in this studies by identify the cut off of Gamma ray log for different lithology such as sand, silt and shale. Facies then further divided based on the log motif as shown in Table 1. Here, log motif is categorize into different trend such as funnel, bell, boxcar, irregular and symmetrical shape.
Table 1: Table of log motif that been used as reference for depositional environment analysis for the sand package of MA-3 and MA-5. Log motif adapted from (Rider,2002).

| Facies                  | Log motif   | Sequence Stratigraphy | Depositional Environment                                                                 | Gamma Ray GR |
|-------------------------|-------------|------------------------|------------------------------------------------------------------------------------------|--------------|
| Coarsening Upward Section (CUS) | Funnel      | Prograding             | • Cresvasse splay • River mouth bar • Delta front • Shore faces                          |              |
| Fining Upward Section (FUS)  | Bell        | Retrograding           | • Fluvial point bar • Tidal point bar • Tidal flat • Marine channel                      |              |
| Cylindrical            | Boxcar      | Aggrading              | • Braided fluvial • Distributary channel-fill • Eolian sand                             |              |
| Serrated               | Irregular   | Aggrading              | • Fluvial floodplain • Storm-dominated shelf • Distal deep-marine slope                  |              |
| Hourglass              | Symmetrical | Prograding & Retrograding | • Regressive to transgressive shore face delta • Offshore shoal • Marsh                 |              |

The result from well log motif from well MA-3 and MA-5 shows that most of the package shows coarsening upward section (CUS). It can be expressed that MA-3 and MA-5 both are dominated by delta and mouth bar. Based on the location of wells shown in Figure 1, even though MA-3 and MA-5 are located far apart but it share the same important feature in the environment of depositional facies. Since than assumption can be done as MA-3 and MA-5 experienced the same depositional environment facies, despite influence of location of the well that is far apart. Thus, the change of the trend of pore pressure has the relation to the environment of depositional facies. So, depositional environment analysis is important in order to enhance the understanding of the pore pressure for future hydrocarbon discovery.

4.3 Porosity

Porosity give the meaning of void volume against the total volume. Porosity plays an important role in geology as it can control the fluid storage. Besides, porosity has the relation to the fluid transport and rock properties. Thus, it can be used for pore pressure analysis in the reservoir. Porosity analysis begin with correction on the Neutron porosity with the Density log and Sonic log for MA-3 and MA-5. The correction was done in the clean wet sand package since the Neutron log give the best result in this sand package as it measure the hydrogen ions that present in the formation. Thus, it will set as reference to the correction of porosity in shale package. The observation done by compare the corrected porosity with the porosity equation that being used previous research such as Gassman, Wyllie and Gardner equation.

Observations based on porosity density and porosity sonic of MA-3 and MA-5 shows that deviation occur at the depths which are top of overpressure. At the depth below the porosity trend show decrease with depth, meanwhile when go deeper depth the porosity trend deviate at the certain depth then remains constant up until certain depth. Even though absent of sonic data in MA-5 but porosity density shows the significant changes. Porosity constant happens due to pressure retaining at that depth which present within the overpressure zone. So, because of the porosity is one of the element that important in the study of overpressure characterization. Thus, the trend of porosity can be an indicator of the overpressure top for the well. Thus, the properties of the shale itself will be used to further analyse the normal compaction trend of the well.
Figure 4: The porosity trend of Sonic log and Density log from MA-3 and MA-5.

Analysis on the pore pressure trend can be used for detection of fluid pressure and porosity evaluation from the well logs. In this study, normal compaction trend was detected using the sonic and porosity data from the well logs. Since the porosity analysis shown that the shale experienced more compaction compare to sandstone, so the analysis on the normal compaction trend is more significant in the shale package. Sonic log and porosity log respond to the changes of pore pressure with depth. Thus, analysis on the normal compaction trend will enhance the understanding on the pore pressure distribution in Miri area. As referred to Figure 4, it shows how the change in sonic log and porosity log to pore pressure in the well. So, overpressure can be defined and identified based on the deviations of the sonic and porosity log from the normal compaction trend.
Figure 5: Schematic response of the Sonic and Porosity log to the normal compaction and overpressure zone. Modified from (Hermanrud et.al, 1998).

5. CONCLUSION

Based on the observations of the porosity analysis, the results show that the corrected porosity of Density log as well as Sonic log is more close and realiable to the neutron porosity data from the well compare to the porosity that is obtained from the existing porosity formula. This happens because the formula is empirically and only suitable to be used in the area that has being tested. Thus, this research will use the corrected porosity to further analysis on the pore pressure trend of Miri area. The result from porosity of density and sonic logs shows the variations based on different facies characterization. Porosity analysis was further analyze to identify the compaction factor of shale package for MA-3 and MA-5.

The trend of pore pressure is related to depositional environment facies. Thus, both have similar depositional environment facies and pore pressure characteristic by overpressure top located within the shale underlying sand interval. As for MA-3 and MA-5, overpressure zone occur in the prograding sand package that shows in coarsening upward motif. Shale experience compaction higher than sand. The deviation of the data from its normal compaction trend shows in MA-3 (2960m) and MA-5 (2090m) indicate the overpressure interval. Thus, shale is significant in order to study the compaction trend of the formation.

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