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Estimation of Overpressures in Onshore Niger Delta Using Wire-Line Data

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Abstract: ***In this study, we have estimated overpressures using well logs from three wells in onshore Niger Delta Field. Key logs required for the prediction were conditioned and quality controlled to meet the standard required for reliable results. The overburden stress (or true vertical stress), normal compaction trends (NCT) and shale velocity trends were generated from the volume of shale, density, gamma, resistivity and sonic logs. Prediction points were picked at depths with thick shale and where there are no washouts (identified from caliper log). Pore pressures in the wells were then predicted using Eaton's exponent of 5 and compared with measured pressures (RFT data). Overpressures were estimated by observing the deviations of the predicted fluid pressures from the hydrostatic pressure line. The results obtained from the analysis reveal that two of the three wells are mildly overpressured at all depths while one well (G-005) experiences hard overpressure at a depth of about 15400 ft. The predicted Pore Pressures also compares favorably with the measured pore pressures at the three well locations, indicating that the Pore Pressure Prediction model used in this work is suitable.***

Keywords: Overpressure, Overburden Stress, Effective stress, Hydrostatic pressure, Wire-line Logs)

1. Introduction

Formation pressure is the pressure experienced by fluid in the pore spaces of subsurface formations. The overburden pressure at any depth is the summation of weight of grains and the pore pressure at that depth. The pressure that the pore fluid has assuming there are no obstacles to fluid flow is known as hydrostatic pressure. Hydrostatic pressure is thus the normal pore pressure while Pore pressure is the actual fluid pressure in the sediments.

A formation is abnormally pressured when the pore fluid pressure is significantly below or above the normal hydrostatic pressure for the depth considered[1]. The difference between the actual pore pressure and the hydrostatic (normal) pressure at a given depth is called overpressure. Overpressure is the pressure which exceeds the pressure of a static column of water or brine [2]. It is the result of the inability of formation fluid to escape at a rate which maintains equilibration with a column of formation water which exists to the surface [3].Overburden stress or lithostatic pressure is the weight of the entire overburden and it increases with depth. The net compressive stress on the rock fabric, that is, the difference between the lithostatic stress and the pore pressure is the effective stress on the formation[4].

An accurate prediction of the subsurface pore pressures is a necessary requirement to safely, economically and efficiently drill the wells required to test and produce oil and natural gas reserves. Pore pressures are easily predicted for normally pressured sediments but challenging when the sediments are abnormally pressured. An understanding of the pore pressure is a requirement of the drilling plan in order to choose proper casing points and design a casing program that will allow the well to be drilled most effectively and maintain well control during drilling and completion operations. Well control events such as formation fluid kicks, lost circulation, surface blowouts and underground blowouts can be avoided with the use of accurate pore pressure and fracture gradients predictions in the design process[5].Pore pressures are largely determined by analysis of relevant data, coupled with knowledge of burial, stress and temperature histories, rock types and their distributions, subsurface structure and reservoir connectivity.

Over pressure detection is based on the premise that pore pressure affects compaction dependent geophysical properties such as density, resistivity and sonic velocity. Shale is the preferred lithology for pore pressure interpretation because they are more responsive to overpressure than most rock types. Consequently, overpressure detection centers around shale deformation behavior [6].

2. Geology of the Study Area

The study location is located in the onshore part of the South-South Niger Delta. The Niger Delta is underlain by three stratigraphic units, the deepest Akata Formation, the middle Agbada Formation and the top Benin Formation. The Benin Formation is mainly made up of continental sand deposits with intercalation of shale and is covered with topmost low velocity layer which in most cases is weathered within which surface waves are excited and generated. Immediately below the Benin Formation is the reservoir sand of the Agbada Formation which is believed to house the oil and gas resource of the Niger Delta.TheAkata Formation is also believed to be the source rock for the petroleum resource and hydrocarbon reservoirs in deep offshore [7].

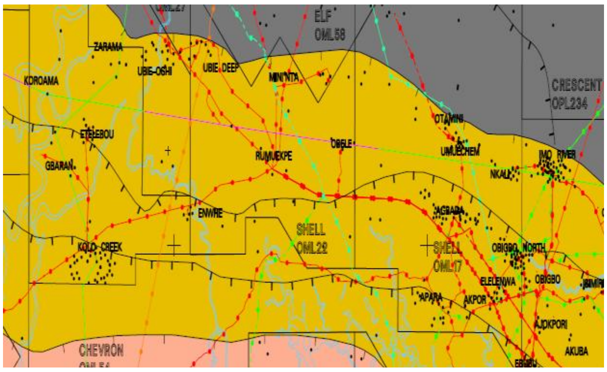

Figure 1: Map of the study area

3. Methodology

A good number of methods have been developed for prediction of overpressure. These methods are grouped under Velocity-based methods, graphical methods (e.g Depth Equivalent Method) and Power Law or Empirical methods. The power law methods include Tau, Eaton's, Bower and Holbrook methods. We use Eaton's method in predicting pore pressure in this work.

The procedure here is to examine the porosity versus depth data and to make a ratio comparison between the recorded and the expected value if the pore pressure were hydrostatic, ie plotted on the normal compaction curve. The form of the Eaton's equation is

$$P_p = s_v - (S_v - P_n)\left(\frac{A_{obs}}{A_{norm}}\right)^x \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where P_p is the pore pressure; S_v is the total vertical stress (overburden or lithostatic pressure); P_n is the normal or hydrostatic pressure; A_{obs} is the observed attribute (sonic travel time, velocity, resistivity etc); A_{norm} is the attribute when pore pressure is normal, and x is an empirical constant [8],[9]. The Eaton (1972) method is used to test pore pressure prediction from sonic log data. The method estimates pore pressure from the ratio of acoustic travel time (Δt) in normally compacted sediments to the observed acoustic travel time [10].

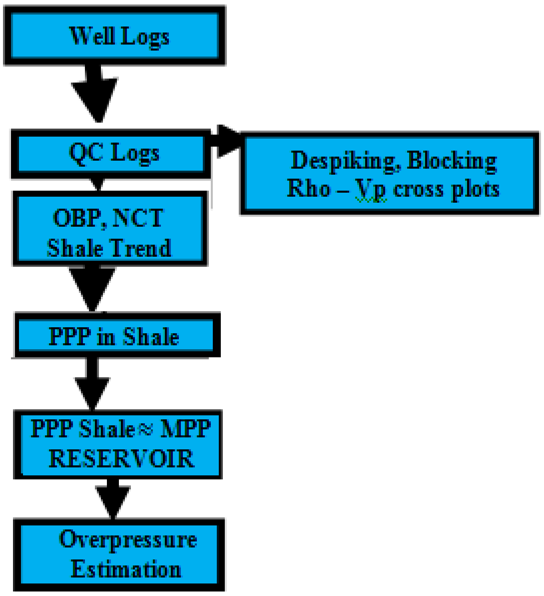

Figure 2 : Work Flow diagram adopted for the overpressure estimation

4. Data Sets

The following Data sets were used:

1. Well logs (gamma, sonic, density, caliper and resistivity logs)
2. Measured pressure data (RFTs)
3. Directional Surveys (deviation data)
4. Checkshots (for calibration and quality control purposes).
5. Well Tops (Markers)

The overburden stress, normal compaction trends (NCT), Hydrostatic pressureand shale velocity trends (V_p - Observed shale velocity and V_n – normal shale velocity) were generated from the volume of shale, density, gamma, resistivity and sonic logs. Pore pressures in the wells were then calculated using equation 1. Prediction points were picked at depths with thick shale and where there are no washouts (identified from caliper log).The pore pressure prediction was carried out using Eaton's Method (with an exponent of 5) and compared with measured pressures (RFT).The logs were plotted converting depth in TVDss (True vertical depth sub surface) into two way time (TWT). Data conditioning and quality control were carried out by doing depth matching and blocking to remove high frequency and noise.

5. Results

The results obtained are hereby presented. We present the log suites and pressure depth plots of the wells.

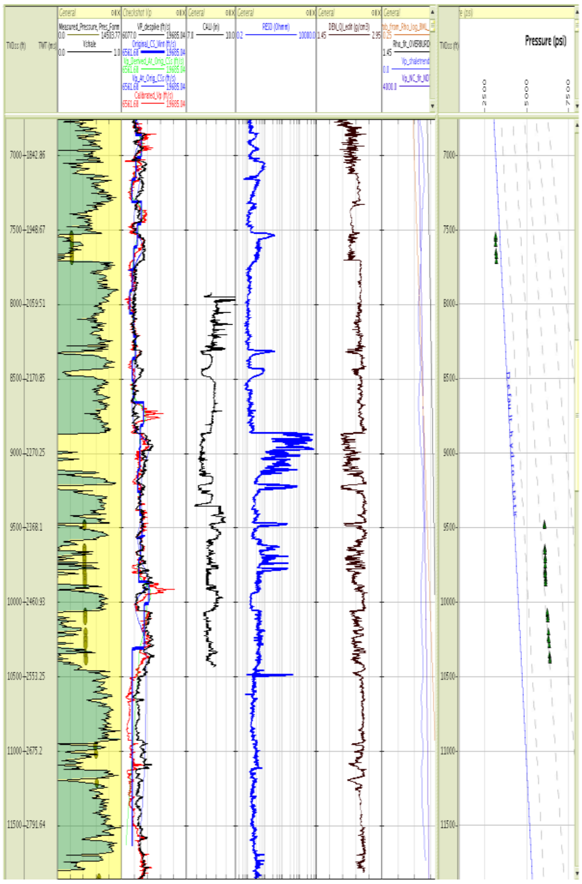

Figure 3: Log view of well A-001

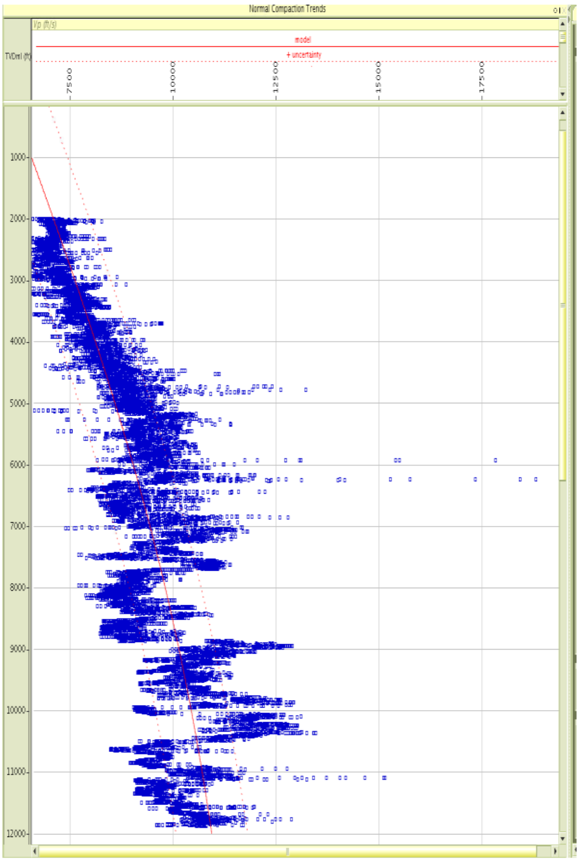

Figure 4: Normal compaction trend of A-001

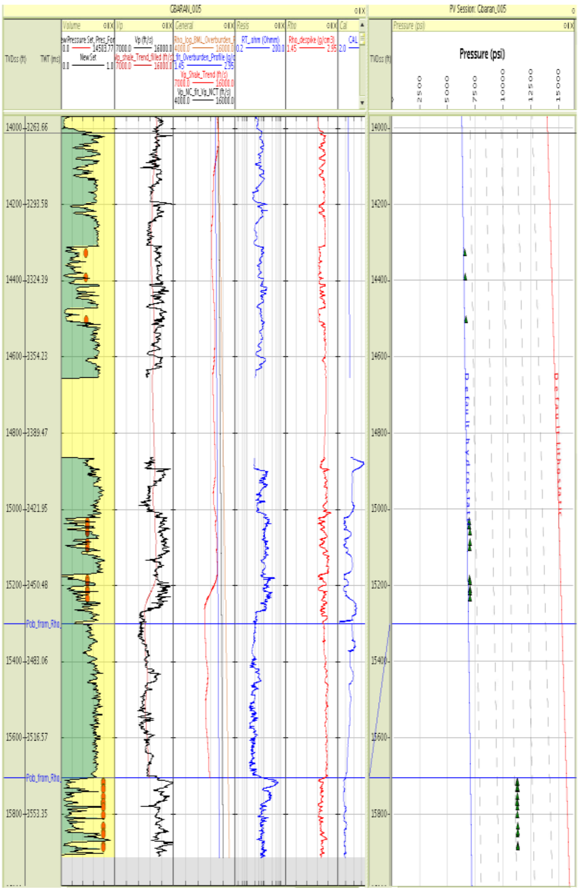

Figure 5: log view of well G-005

The pressure -depth (P-Z) plots of the wells are presented below

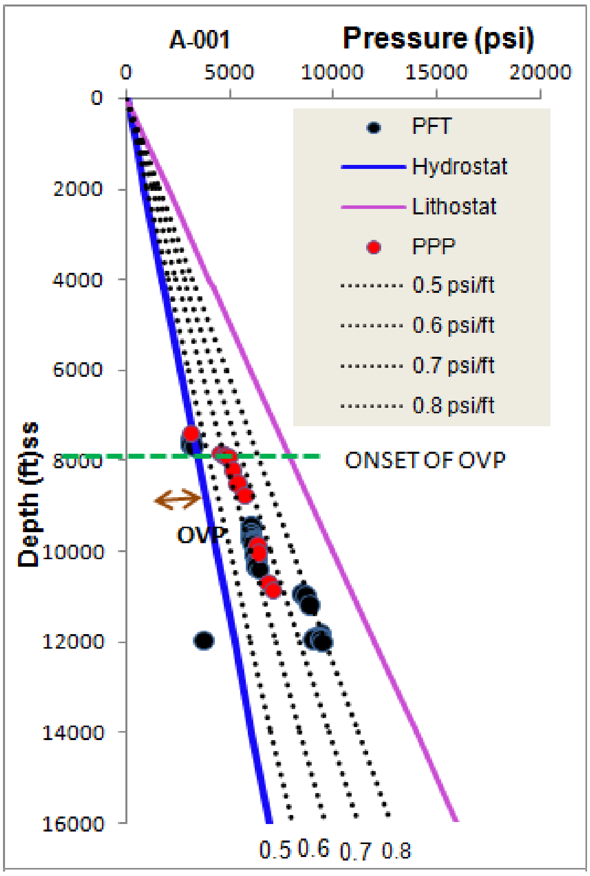

Figure 6: P-Z plot and overpressure estimation of well A-001

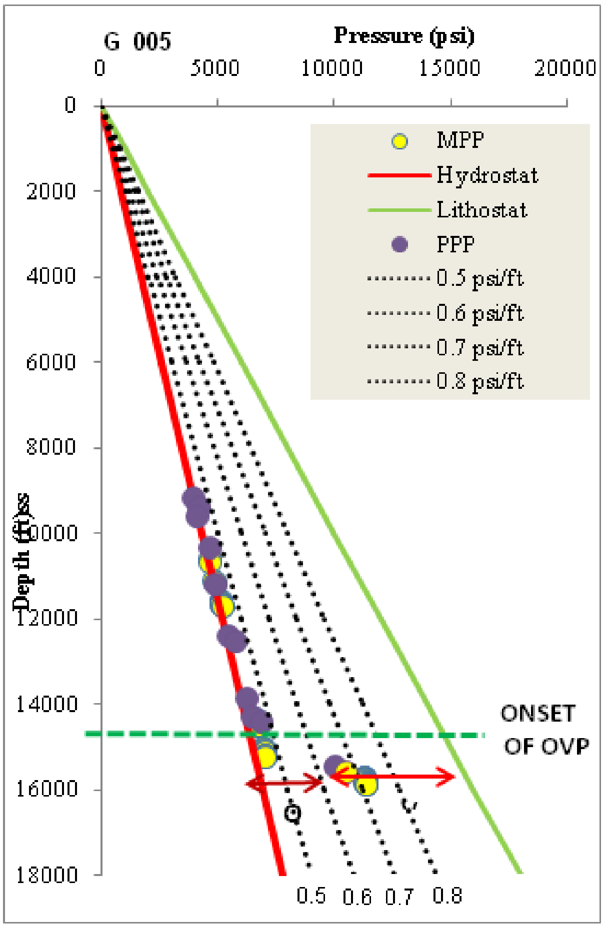

Figure 7: P-Z plot and overpressure estimation of well G-005

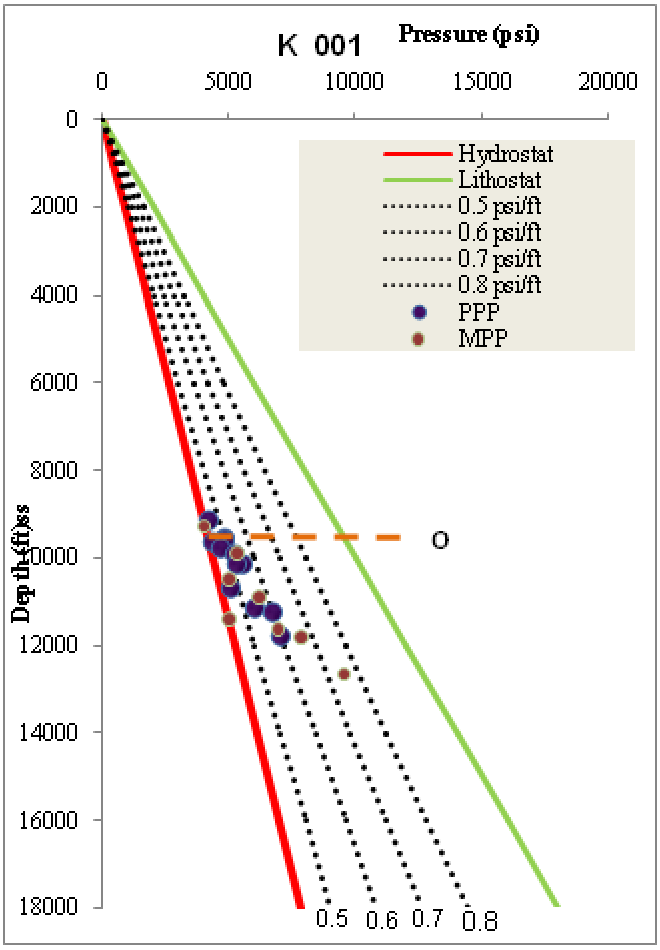

Figure 8: *P-Z plot and overpressure estimation of well* K-001

6. Discussion of Results

Presented in the previous section are the results obtained from analysis of the petrophysical data from the wells used in this study. From the pressure regimes constructed, the top of overpressures have been identified in all the wells. The overburden stress (or true vertical stress), normal compaction trends and shale velocity trends were generated from the volume of shale, density and sonic logs. Prediction points were picked at appropriate depths. Areas of thick shale are considered suitable for overpressure prediction because log responses to overpressure effects are higher in shale. The reverse is the case in sand due to high porosity and allowing dewatering during compaction which counters the effects of overpressure. Also, areas of washouts suggest possible deviations from wellbore diameter which will affect the prediction of pressure at those depths.

The overpressure prediction is all inclusive because it takes care of measured pore pressure (MPP) obtained from the repeated formation tests (RFTs) and the predicted formation pressure using the Ben Eaton Model. The results obtained from the analysis reveal that two out of the three wells under review are mildly overpressured at all depths. In Niger Delta area, the normal hydrostatic pressure gradient is usually averaged to be 0.435 psi/ft for fresh water and 0.465 psi/ft for saline water. The log responses have also been compared with models and found to reveal presence of overpressures in the wells. Strong similarities also exist between the Measure Pressure (MPP) and Predicted Pressures at the three well locations, indicating that the Pore Pressure Prediction model used in this work is suitable.

At well A-001, normal pressure is observed below depth of 800ft. Onset of overpressure is observed at a depth of 800ft (fig 6). As observed in Fig 4, the normal compaction trend line shows a shift at about this depth, which is an indication of onset of overpressure. At this depth the pressure at the well exceeds hydrostatic (normal) pressure. An average formation pressure gradient of about 0.65 psi/ft was observed and this is classified as **MILD OVERPRESSURE**. The mild overpressure gradient continued steadily from depth of 800ft to about 1100ft. Beyond this depth, Hard over pressure was observed with 0.80psi/ft gradient.

Well G-005 maintains hydrostatic pressure until at a depth of 15500ft where there is a mild overpressure (figure 7). The onset of overpressure at this well is observed at depth beyond 1500ft and it is mild (not up to 8psi/ft). At well K-001, the onset of overpressure is observed at a depth of about 9600ft (fig 8). The pore pressure predicted with Eaton's model also compares favorably with the measured pressure. The formation pressure almost approximates the minimum effective stress (fracture gradient) as the depth increases.

7. Conclusion

The main objective of this work was to estimate overpressures using well logs from three (3) exploratory wells in onshore Niger Delta. This has been done successfully and meaningful results obtained.Pore pressures were predicted using Eaton's exponent of 5 and compared with measured pressures (RFT data) from same wells. Overpressure estimations were carried by observing the deviations of the predicted fluid pressures from the hydrostatic pressure line.The results obtained from the analysis reveal that two out of the three wells under review are mildly overpressured at all depths. The predicted fluid pressures compared favorably with the Measure Pressure (MPP) at all the well locations, indicating that the Pore Pressure Prediction model used in this work is suitable

8. Acknowledgement

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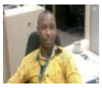

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