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Pore Pressure Prediction in an Offshore Niger Delta Field, Nigeria Using Seismic and Petro physics Parameter – An Empirical Model Development.

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Abstract
Over pressured sedimentary formations are associated with deep water Niger Delta basins, with a formation average pressure gradient which is 0.465psi/ft . A pressure gradient higher than this is identified as an abnormal over pressured zones, where this will serve as resource for hydrocarbon prospective prediction or evaluation. This explains a significant safety concern while drilling. While formation pressure gradient less than this is regarded as abnormal sub pressure gradient. This Pore pressure prediction is aimed at Improving existing pore pressure prediction models with its corresponding depth of occurrence, top of over pressure and sub pressure zones which is an important procedure to be considered in well design and casing designs.
The modified derived Eaton's model in validating pore pressure in offset wells for the offshore Niger- Delta Field X where an excellent match of pore pressure determined from this data and the simplicity of obtaining the pore pressure has given a better evaluated result in comparison with that of Eaton's model in validating pore pressure in the Niger- Delta Field using seismic and petro physics data such as sonic log, porosity logs, density logs and so,on .
Therefore, the modified Eaton's derived empirical model equation is an empirical correlation that can be utilized to model the underground/ subsurface interval transit time in evaluating the pore pressure of any subsurface geo formations where in the first instance computing porosity Φ from an entire field to another field as the case may be. The concept take into considerations calibrated petro physical parameters, estimating the ratio of sonic transit time at each well point as derived for the empirical model. The developed model is then validated and compared with the existing Eaton's model with a varied number of well log data from the field. Considering Gamma ray log of the identified well 4 depicts the subsurface to be identified as a mud rock dominated sequence which demonstrates overpressures culminated by under- compaction , this is validated by the pressure profile in figure 4.10a and 4.11a. This explains a characterized abnormal pore pressure change with an amount able depth parallel to the overburden pressure gradient , of course form depth of 4091,62ftss to 8816.96ftss with a corresponding pore pressure increase from 2739.233Psi to 5911.3727Psi respectively. An abrupt break which reoccur between 8329.4196ftss to 9093.09ftss where the pressure shows 6597.9738Psi and 7500.0196Psi. This indicates or possibly explains presence of micro fractures which have been caused by Hydrocarbon generation.

Keywords: *Correlation, Petro physics, Eaton's Model, Pressure Gradients, Pore Pressure.*

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I. INTRODUCTION

Overpressure is any pressure in excess of the hydrostatic pressure. Detection and evaluation of over pressured formation are significant to exploration, Drilling, work over and production of hydrocarbons as oil and gas distribution is associated to regional and local area subsurface pressures and temperatures. Ideas, Knowledge and understanding of the expected pore pressure and fracture gradients is the background for the efficient drilling of oil and gas wells, with effective mud densities, the designed completion program which must be effective if a safe measure and allows for the killing of the well without gross formation damage and the proper engineering of casing plans.

Abnormally high pore fluid pressures are encountered in most part of the world in oil and gas formations ranging in age from Pleistocene to the Cambrian. Overpressure or geopressure zones has been identified as major cause of drilling risks and a significant challenge in exploration, drilling and exploration of oil and gas reserves.

Typical pressures could occur as shallow as a few hundred meters below the surface or possibly at depths exceeding 6200meters and could be represented in shale/sand sequences and/or carbonate-evaporite sections(Petro consultants,inc,1996)

Causes of Abnormal Pore Pressure Abnormal pore pressure is developed as a result of a combination of geological, geochemical, geophysical and mechanical processes. These causes may be summarized under: Depositional Effects , Diagenetic Processes ,Tectonic Effects
Structural Causes; and Thermodynamic Effects.
1) Depositional Effects
1.1 Undercompaction of shales: Undercompaction of sediments is the process whereby abnormal pore pressure is developed as a result of a disruption of the balance between rate of sedimentation of clays and the rate of expulsion of the pore fluids as the clays compact with burial.
1.2 Deposition of evaporates: The deposition of evaporites can create high abnormal pore pressures in the surrounding zones with the pore pressure approaching the overburden gradient. When salt is deposited, the pore fluids in the underlying formations cannot escape and therefore become trapped and abnormally pressured.
1.3 Diagenetic Process: With increasing pressure and temperature, sediments undergo a process of chemical and physical changes collectively known as diagenesis. Diagenesis is the alteration of sediments and their constituent minerals during post depositional compaction. Diagenetic processes include the formation of new minerals, recrystallisation and lithification. Diagenesis may result in volume changes and water generation which if occurring in a seabed environment may lead to both abnormal or sub-normal pore pressure.
1.4 Tectonic Effects: Tectonic activity can result in the development of abnormal pore pressure as a result of a variety of mechanisms including: folding, faulting, uplift and salt diaparism.
1.5 Structural Causes: Reservoir Structure Abnormal pore pressure can exist in both horizontal and non-horizontal reservoir structures which contain pore fluids of differing densities i.e. water, oil and gas. Examples of structures in which this may occur are lenticular reservoirs, dipping reservoirs and anticlinal reservoirs. In dipping reservoirs, formation pressures which are normal in the deepest water zone of the reservoir, will be transmitted to the updip part of the structure.(Kesarwani,2013) .

A) OVERPRESSURE PREDICTION DRIVEN SEISMIC VELOCITY RESPONSE

The activity involved with the prevention of drilling mud losses or kicks, the drilling hazards assessment in relation with expected reservoir pressure, the casing program and so on are inherent industry problems linked with prediction and evaluation of pore pressure before and at the time of exploration well drilling(Bell,1999) ;(Huffman,2002).

It has been established that seismic velocities in their different modifications is a major and the only input before starting up of exploration drilling operations predictions. This is actually obvious for green areas or and frontier well depth intervals within the exploration areas. As this is obvious, offset wells inherent with drilling information appear not recorded. While the target overpressure signal extraction from seismic velocity input is centered on theoretically predicted and pragmatically proven facts that excess overpressure anomalous can variably be recorded in seismic data and thereby extractable and interpretable from associated seismic velocity information.

Moreover, the overpressure concept affects the elastic properties of sedimentary rocks as such that it produces the negative departure of seismic velocity from normal trend expected in agreement with positive velocity trend observed along interfering directions; temperature/depth increase and formation rock consideration(Reynolds 1970; Keyser et al…1991). This expected target would be called a target phenomenon─ Over pressure Driven velocity Response(ODVR).

It is imperative that its obvious that overpressure response potentially observable and extractable from amplitude/frequency characteristic of seismic wave field; an example is the frequency depended attenuation as well as quality factor would not be taken into consideration unlike the traditional input in the phenomenon of overpressure prediction. Application to theses purposes has to be proven on practice despite the optimism proclaimed from researchers perception(Kuster, Toksoz 1974).

Experience has shown that expected overpressure target signal is to a considerable level disguised in a seismic wave field dynamics and its picking out/ trace out constitutes even more challenge task for processing and interpreting than it is for controlled velocity response(Madatov et al, 1991).

Strategy taken into consideration before drilling of overpressure prediction centered on the overpressure driven velocity response concept usually implied processing with another factor “interpretation” phases which are non explicitly carrying connotations of uncertainty or unknowns. The expression of previous fact, that is, the history of its actaualization incepted from the initial experiences in the Gulf of mexico(Pemebaker,1968) and the offshore location of the Capsian sea(Dobymin,1978).

In current times, the pragmatic experience identifies many of the restrained estimations of the finally possible accuracy of this predictions and its usage for strongly deep hydrocarbon targets(Al-Ghalabi,1994). The conventionally recognized expert N.Dutta in his recent review(Dutta,2002b) that " techniques based on seismic information have reliability and validity naturally limited by vertical and lateral resolution of seismic reflection method and are absolutely dependable unless sensitive to overpressure parameter velocity characterized for purposes by utilizing model inherent processing methodology"

Considering that the majority of the well valid for successive utilization of the overpressure driven velocity response based on before-drill prediction emanated from the Higher elastic sections inherent with geologically short and continuous burial history.

A lot of the published discussions centered around these challenges were targeted on seismic attribute improvements; a requirement for prediction phenomenon viz-a-viz all the work flow phases from data acquisition till velocity targeted processing and analysis(Mattew and Kelly,1967). In relation to the conversion of rock velocity abnormality to overpressure abnormality; it was considered to stand out, of which state of stability operation centered on simple bijective Terzaghi' single –axial stress model(Terzaghi,1948).

A closer study(Waples and Kamata,1993) has reveal that the authenticity of this mechanical axail stress model is actually limited by shale-clay lithology and rock consolidation depth grape(sedimentary) in addition to no significant erosion and processes as such as diagenesis that do occur during burial history.

The more general case which was an extension of this mechanical model led to both of hybrid class of the earth models integrating components of basing scale geo fluid dynamics by utilizing the principles of one-dimensional rock mechanic(Bowers,1995).

The deviation of rock velocity from the trendline/range of values incorporated with usually stressed porous rock remains mainly sensitive to overpressure driven seismically response.

B) OVERPRESSURE DETECTION USING PETROPHYSICS PARAMETERS

Electrical properties, radioactive properties, Elastic & Acoustic properties, Density and Thermal Conductivity are the physical properties of rocks that are of importance in Formation Evaluation and Well log interpretation. These various properties form the foundation of groups of well logs used widely in oil and gas field operation that spread the span of oil field endeavor from Exploration through drilling, completion of oil and gas wells and estimation of reserves.

Conventionally, the application of petro physics in the detection of overpressure is centered on log analysis. It is established that log analysis is a common procedure for pore pressure determination in both offset wells and actual drilling. The following various petro physics parameters used in abnormal pressure detection are discussed and stated below:

i) SHALE RESISTIVITY METHOD

It is conventionally observed that the shale resistivity increases with depth since porosity decreases as a result of compaction . It is generally accepted that in an over pressured location, the resistivity of shale departs from normal trend line to lower-than-normal, sediment compaction is a feature determined by function of mean effective stress and stress differential (Goultry, 2004) this is as a result due to:

i) Porosity increase with Under compaction leading to Higher water content

ii) Increase in mobility of dissolved and exchangeable ions causing the higher conductivity as a result of Increase in temperature.

ii) ACOUSTIC METHOD

The Estimation of the formation pressure of reservoirs from adjacent shale acoustic log. The following steps are to be considered:

i)The very top of the over pressured formation is determined by noting the depth by which the plotted points deviate from the trend line.

ii) The "usual compaction trend" for the area of interest is developed by plotting the logarithm of .

Remote detection and prediction of high pore pressure regions seismic or interval transit time(Hottman and Johnson, 1965). Numerous empirical models are available to link P wave velocity(Vp) to overpressure, though using Pwave information alone can give extravagant results.

In theoretical application, it has been expressed that at or above critical porosity, where sediment has been converted into a suspension, Vp(P- wave velocity) will be given by the Woods Equation for suspensions, and as such the sediment will close their shear strength and Vs will decrease to zero(Nur et al,1995)

Based on the condition of Vs decrease to zero, the corresponding Vp-Vs ratio should show a large change as differential pressure goes to zero at porosity close to the critical porosity, this suggested(Hamilton and Castagna,1999).
Acoustic log in the usually presumed shale's depicts a relationship between the column logarithmic of shale travel time(and depth. If intervals of abnormal compaction are penetrated, the resulting data points will deviate from the normal compaction trend.
If possibly an overpressured formation is encountered or come by, the data points will diverge from the normal trend towards abnormally high transit times for a given burial depth.

iii)BULK DENSIY METHOD
The bulk density value; is the value of the density of rock as it occurs in nature, for instance in well logging investigation, it is the density of the rock with the pore volume extremely filled or occupied with fluid. The bulk density equation commonly used to make a computation of porosity from well log obtained derived bulk density is given:
Porosity(Φ) = (1.0)

Where Db is the bulk density, Dg is the grain density, and, Df is the fluid density. (Athys,1930).
Sediment Compaction is a function of mean effective stress and differential stress (Goultry,2004), but traditional methods have generally been applied on the assumption that porosity is a function of vertical effective stress. The transition from normal to abnormal pressures do occur at the depth where it deviation from normal trend is observed.

(iv)INTERVAL TRANSIT TIME(SONIC LOG)
One of the major evaluation tool for formation evaluation and petro physics determination as well as most successful pressure tool is the Sonic Log. Where sonic transit log is available, (Ramdhan & Goultry,2011) used

$t_0 t_m t_m$. (1.1)

Where Δt = Transit time;
Δt_0=Initial surface transit time ,Δt_m; Matrix transit time, b =Compaction constant(m^{-1}); and z = depth in(m).
The period of change from normal trend(usual trend) to surnormal pressures(abnormal) occur at that depth where deviation from the normal trend is observed or examined.

v) NEUTRON LOGGING METHOD
Neutron log is one of the integral arm of the conventional porosity logs and it measures the amount of hydrogen present in the formation, and interprets this to be a volume fraction of water present in the formation. (Ramdhan & Goultry,2010) preferred to use neutron and density logs in combination to identify clean shales, with NPHI-DPHI > 18% as their cut off threshold This fundamental interpretation is only valid for $Caco_3$(limestone formation) containing fresh waters, depending on the lithologies or when hydrocarbons are present in such case corrections are required. The neutron log is not strongly suitable for efficient qualitative porosity interpretation but is extensively utilized in combination with density log for lithology determination and for differentiating between oil and gas.

vi) SHALE FORMATION FACTOR METHOD
Formation factor (f) equals to the ratio of the resistivity of the hundred percent water saturated rock piece to the resistivity of the water solution contained in the rock. The intrinsic characteristic of the rock especially a the formation factor ; a limiting factor achievable or determined with reliability only when the interpose water solution is strongly salt saturated. The apparent formation factor, usually obtained as a major function of porosity, salinity of water filling the rock pores, geometry of pores, content of clay and presence of electrically conductive solid matter.
(1.2)
In addition, the formation factor can be established by Archies formula:

$$F = \Phi^{-M} \quad (1.3)$$

Where the exponent M is termed the "cementation factor" and it varies with the degree of rock consolidation. Athys(1930) equation
(1.4)
(1.5)
Where = Initial surface porosity(%), c = Compaction constant(m^{-1}), Φ =Porosity(%) and Z = Depth in (m).
Depth versus formation factor logarithm is plotted and then formation pore pressure can be determined as thus:

As given "f" at a predetermined depth called "D". Find the depth on the straight line portion of the curve where the same value of "f" exists in the curve. It is on this estimation that it is called Equivalent depth. De.
Evaluate the net overburden Pressure P_O at the depth.

Formation Pressure can then be estimated from :

O

II. REGIONAL GEOLOGY

The Niger Delta is the largest wetland in the world, it covers an area of 70,000 square kilometres and consists of a number of characteristic ecological zones, sandy, coastal ridge barriers, mangroves, freshwater. The Niger Delta occurs at the most important sedimentary basin in sub-sahara Africa with due regards to its hydrocarbon potential.

The Niger Delta were deposited as the delta built out along the axis of the Anambra basin. It extends from about longitude3-9 degree North. The three formations are locally designed(from the bottom) as Akata formation, Agbada formation and Benin formation respectively

However, of the three formations the Agbada formation constitutes the main reservoir of Hydrocarbon in the Niger. This formation has therefore been given greater attention to in the Niger Delta. The location of the Niger Delta is situated on the West African Continental margin on the peak of the Gulf of Guinea. The coastal plain, continental shelf and slope of Nigeria and western Cameroon(Tertiary Cameroon volcanic Trend) including the northern territorial waters of Equatorial Guinea. Along the Wesrern Cameroon and equatorial guinea region known as the Rio Del Rey Basin. It is expressed as a significant regressive sequence and the most producing province in the world as perhaps hydrocarbon.

Examining Nigeria, the basin occurs between latitude 4^0N and 6^0N and longitude 30E and 90E in the southern region of Nigeria and its known to be one of the largest in the world. Its recognized as the world largest deltas, covering about an areal extent of 75,000km^2 while it extends from its peak to its mouth more than 300km. Though on a global view, the tertiary delta takes into consideration an areal which covers close to 211,000km^2 and grow southwards out of the Anambra basin of the benue trough.

III. METHODOLOGY

Pore pressure and over pressure detection was carried out using data gotten from an offshore Field X. The data include a 3D seismic data with two way travel time and a suite of a wellbore petrophysical data comprising; Interval Transit Time, Acoustic, Density and Sonic Porosity.

Interpretation of the sourced data was carried out using an empirical model development, a modified Eatons conventional model. The modified model was utilized to make an analysis of the petroleum exploration data from an offshore Niger Delta Field X. This data gotten is subsequently validated and compared with an existing pore pressure prediction model known as Eaton's Model; the model thus:

The modified Eaton's model **STEPS** and **DERIVATION** is gotten as thus:

STEPS

1 As laboratory data is not available, matrix grain density , fluid density and formation bulk density , read from seismic data or well logs. Composite seismic-to-well logs tie is shown in figure 1.9

2 Porosity known to be a vital petro physical parameter in the determination of pore pressure prediction technique evaluated from:

Or

3. Considering the field porosity log record used in Figure 1.9, the density values are read off from table 1.1, column 3 and substituted into equation 1.8a as to determine the porosity, which could be read off as well as available on the type log from column 2, table 1.1. Where 2.65 g/cc, 520 = 189 and 1.074 g/cc.

4. A plot average porosity, vs Depth(ftss), is presented in figure 1.1

5. The determined surface porosity or mudline porosity is determined from figure 1.1 as = = 0.45 (can be from literature) as intercept at zero depth or at seafloor.

6. The above evaluated porosity values, , are so still better calibrated with the known geology of such environment(in this case, the offshore Niger Delta basin) with the below equation:

This is an equation of an exponential calibration. In this case = 0.45 and K, the porosity decay constant is determined as follows:

DERIVATION

= 0.45 which is determined will be utilized for the offshore porosity formation examined, which is at depth zero , that is at sea floor, which means a mud line where the True vertical depth is zero.

Therefore from equation above which is equation 1.9, that is;

Lets get K as the subject and determining K;

The determination of pore pressure utilizing the values of the petro physical parameters at the lithology of shale while the natural shaly formation is gotten at depth of 6328.05ft, where porosity from the column of the table shows 0.21 from read off.
Input the value of formation porosity(and surface porosity or rather mud line porosity i.e. into equation 1.11, therefore we have:

$$\mathbf{K = 0.0001204ft^{-1}}$$

This simply shows that **= 0.45**$\mathbf{e^{-0.0001204Ds.}}$

7. Equation 1.12 will therefore be used to evaluate for the calibration and the result will be presented in column 5, table 1.1 presented.

Equation of elastic wave velocities in heterogeneous and porous media from Wyllie's (1956) could be considered into seismic velocities which are probably dependent on the formation porosities and even on changes with depth. Equation for interval transit time was given as:

= (1**-**) +

Where is the matrix interval transit time and is the fluid transit time.

8. Sonic log or seismic data were used to obtain the average interval transit time, as in column 4, table 1.1

Therefore in terms of , equation 1.13 can be rewritten as:

=

Substituting = 208 as the pore fluid 100,000ppm Sodium Chloride into equation 1.13a , where it becomes

=

Calibrated values of porosity in table 1.1 are inputted into Equation 1.13b to obtain the field matrix time as shown in column 6 of the table 1.1. And thereafter a plot of against relationship is presented in figure 1.2.

9. To determine the intercept which explains the lower limit of the shale lithology, then we plot against . Alternatively we can plot .

10 Normal compaction trend line from from fig 1.3, for transit time of the matrix rock i.e is evaluated as:

= 60 + 150

Equation 1.14 to be substituted into equation 1.13 gives

= (60 + 150)(1-) + 208

The above equation is evaluated to become:

= 60 + 298 **-** 150

Note that , then substituting the above equation 1.12 into Equation 1.15 becomes:

=

Where is the interval transit time(for a normally pressured formation, is the surface porosity or mud line porosity(which s porosity at zero depth) for any kind of subsurface formation in any field.

10. The modified Eaton's model is utilized in this case to determine the Pore pressure gradient as adapted .

11. At each depth interval / point, formation pressure is to be determined at those depths, doing this, a chart is used in obtaining value read from the correlation and then multiply with depth of that pre determined point.

MODEL VALIDATION

The Adapted Eaton's Model Techniques of Pore Pressure Predictions

Pore pressure prediction method of a stress dependent through the introduction of an "Eaton" variable into the effective stress equation. This will be used for my model validation. This model takes into consideration the impact of matrix and mud line velocities or its transit time on the prediction process for which the equation, that is Equation 1.16 did for the Over pressured Niger Delta Basin.

Effective stress is defined by:

=

The variable Eaton's introduced:

Where

Where is the transit time in shale's at the normal pressure condition while is the transit time in shale's obtained from well logs. i.e , also to be taken as which is average interval transit time as obtained from from sonic log as in column 4, table 1.1.

Therefore, the pore pressure can be calculated for a normally interval transit time,

This equation could now be modified to fit the geologic setting by substituting the derived empirical formula into it as:
Note = which is interval transit time as obtained from well logs or seismic log which is

For which at Ds =0, = 0 and = , the above equation becomes:

Equation 1.21 is the newly derived equation for estimating pore pressure in this over pressured field.

CASE APPLICATION
The examination of this case is to verify the adapted Eaton's model stress dependent for pore pressure prediction which is introduced into the effective stress equation. The examined sedimentary basin is an over pressured reservoir located in the offshore Niger Delta. It is located some far kilometers west of Port Harcourt with a reservoir with thickness between 3900-13,500ftss.

IV. DISCUSSION OF RESULTS

DATA ANALYSIS AND INTERPRETATION
Presented in Figure 1.2 is the base Map showing the seismic cross lines, seismic in lines and well locations. Field data were provided and validation of results in this project were revealed by the equation of Eaton's modified model (Equation 1.21). Figure 1.3 is the interpretation window(Seismic) of inline 6100 from which the usual two way travel time could be obtained(TWT).
The result is validated in the plot of pressure vs. depth in Figure1.10 (1.10a and 1.10b) and 1.11 (1.11a and 1.11b) for estimated pore pressure trend for both well 4 and well 5 with empirical and Eaton's model. The data for this research is used to make plots of figure 1.1 and to determine the pore pressure of the eaton's modified equation using the petrophysical parameters.

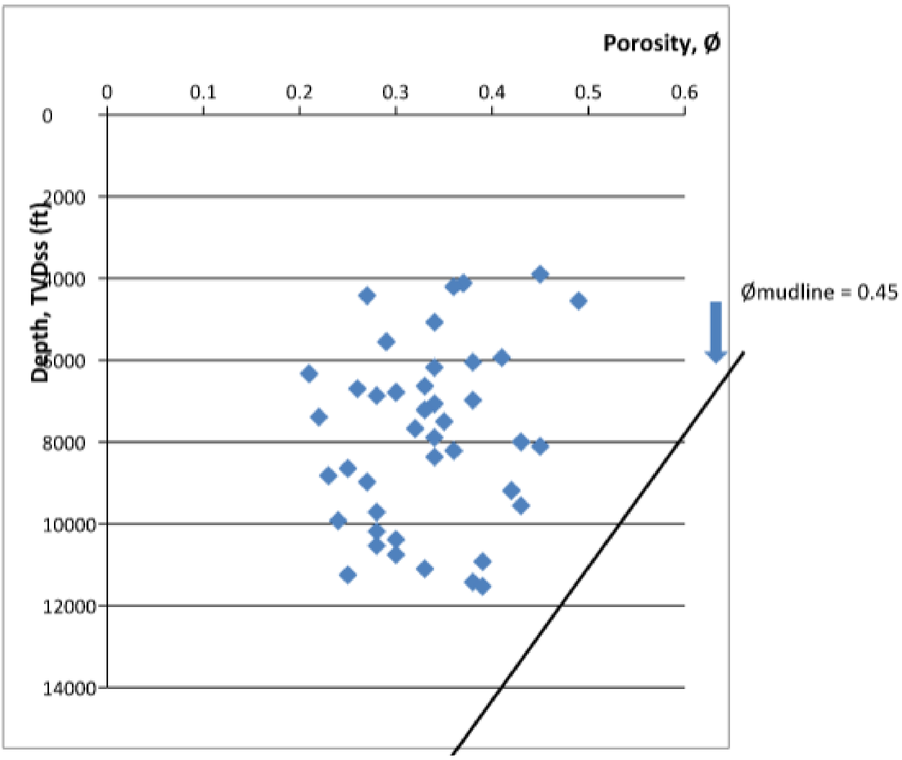


Figure 1.1 : A Plot of Porosity versus Depth in Field X

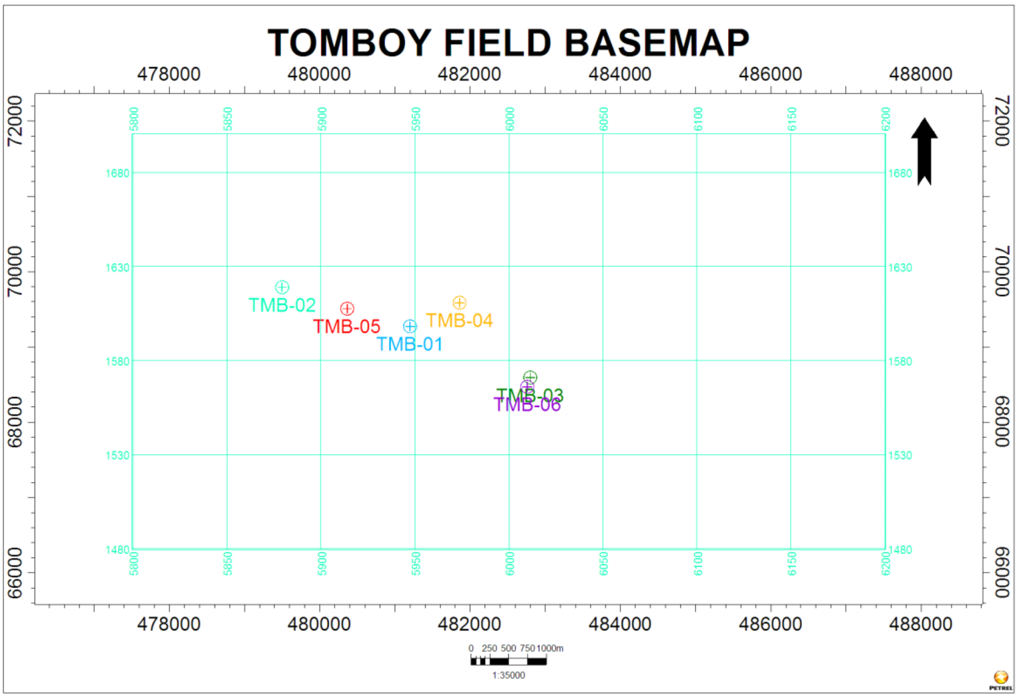


Figure 1.2 : Base Map of Field X Offshore Niger- Delta Basin Showing Seismic and Well Location

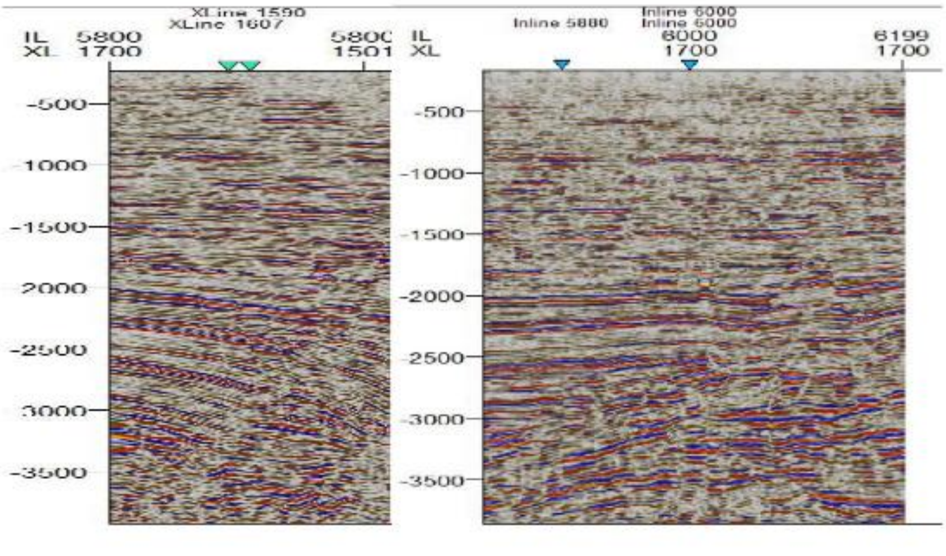


Figure 1.3: Seismic Interpretation Window of inline 6100m Data Section (Database Review)

PORE PRESSURE FROM THE VELOCITY MODEL FOR WELL 4

In Figure 1.4, this shows the comparison and validation where it is shown of subsurface pore pressure profile. A critical process in actualizing pore pressure analysis is to select the clean shale's in well logs. Hitherto to the application of the modified Eaton's model, there is need to obtain the shale porosity from density log and or interval transit time log. It is of note that clay minerals have a crystalline structure that contain a significant level of radioactive elements than sandstones. In this wise, gamma ray data in well logs can be utilized to differentiate shale intervals from those of other peculiar lithologies.

Furthermore, the pore pressure gradient is estimated with the modified transit time Eaton's model(Equation 1.20 and Equation 1.21) with parameters derived from well 4. For the research studied, considering the porosity data, the normal compaction trend in porosity is analyzed based on Equation 1.21 with the constituted parameters such as = 0.45 and C= 0.0001204 as shown in figures 1.1, 1.40 and 1.50.

Critically observing the gamma ray log, the well is a mud rock dominated sequence and the overpressure existence was a result of under compaction; this is validated by the profile pressure in Figure 1.40 to be conditioned with an abnormal pore pressure change with change and with depth that is sub- parallel to the lithostatic (Overburden) pressure gradient from depth of 4091.62ftss to 8816.96ftss where the corresponding pore pressure was 2739.233Psi at 4091.62ftss and sudden abrupt drop to 5911.3727Psi. An abrupt break as well occurred between 8329.4196ftss to 9093.09ftss where the pressure shows 6597.9738Psi and 7500.0196Psi. This indicates or explains possible presence of micro fractures which could have been caused by Hydrocarbon generation.

PP FROM EATON'S MODEL4

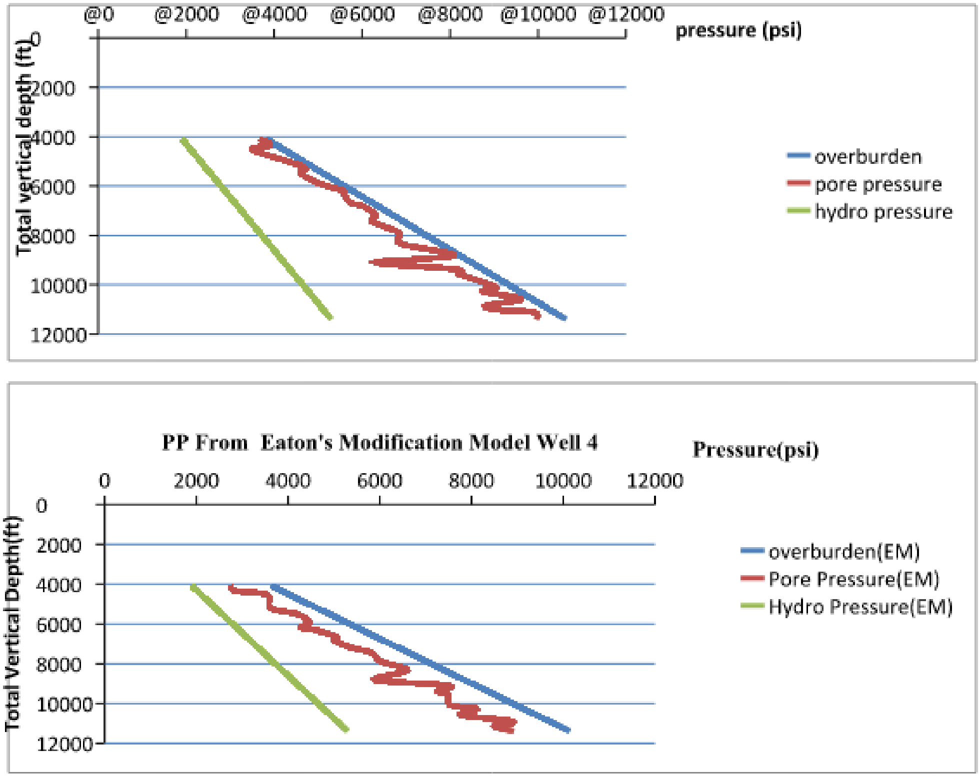


FIG 1.4a: ESTIMATED PORE PRESSURE TREND FOR WELL 4 WITH EATON'S MODEL AND EATON'S MODIFICATION MODEL.

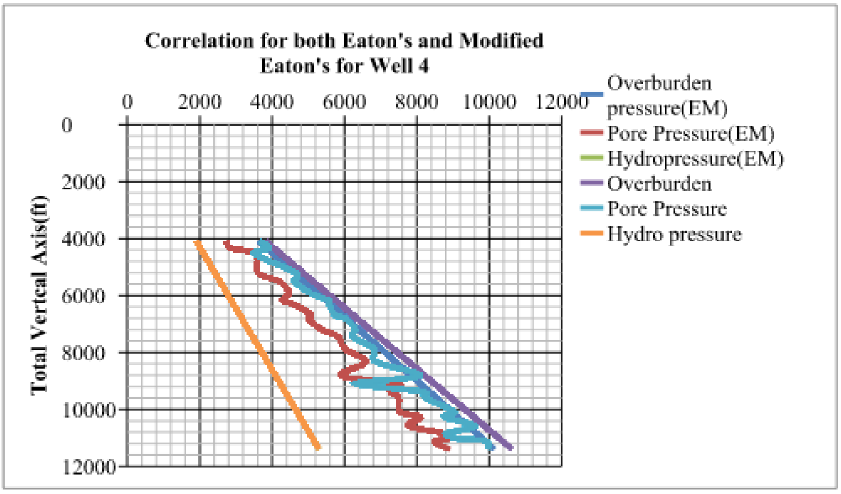


FIGURE 1.4b: EATON'S MODIFICATION AND EATON'S MODEL CORRELATION FOR PORE PRESSURE TREND FOR WELL 4.

PORE PRESSURE FROM VELOCITY MODEL FOR WELL5

Wyllie's equation i.e equation 1.13 is used to determine the porosity from shale transit time using and Applying the porosity data set, the normal compaction trend in porosity is analyzed based on Equation 1.12 with mud porosity () = 0.45 and C = 0.0001204 ft^{-1}

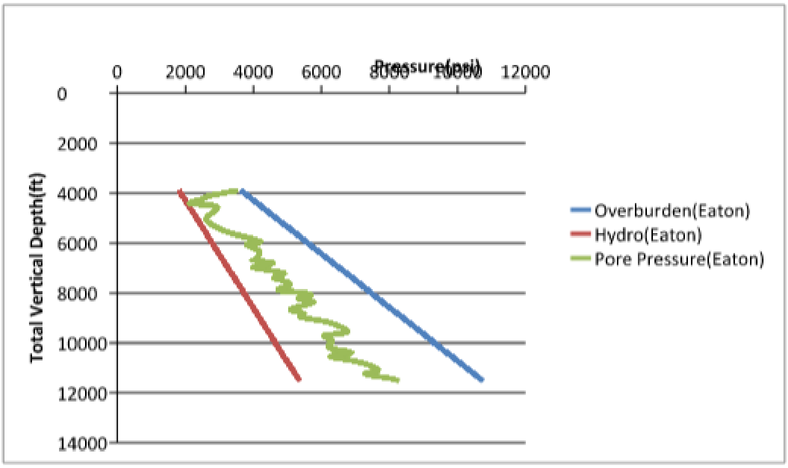
The dominated mud rock sequence validated the overpressures generated by under compaction in Figure 1.5 characterized by an abnormal pore pressure change with depth.

Top of Overpressure existed at depth of 11,421.53ftss and the zone proceeds till 11,529.64ftss excepts at some points like 6328.05ftss, 7389.93ftss, 8646.43ftss and 9925.94ftss where there are abrupt breaks in formation pressure which indicates possible presence of micro fractures possibly catalyzed by hydrocarbon generation. Though along the profile there were minor breaks along the trend.

Summarily, comparing the pressure profile distributions from existing Eaton's method(as shown in figures 1.5a, 1.5b) to the pore pressure obtained from the modified Eaton's model for the over pressured field and correlations of the two models, this empirical model gives a good matching result for estimated pore pressure.

The pore pressures for each of the depth on the data was determined using the derived eaton's model. The data for this field is propriety natured.

PP From Eaton's Model Well 5



PP From Eaton's Modified Model Well 5

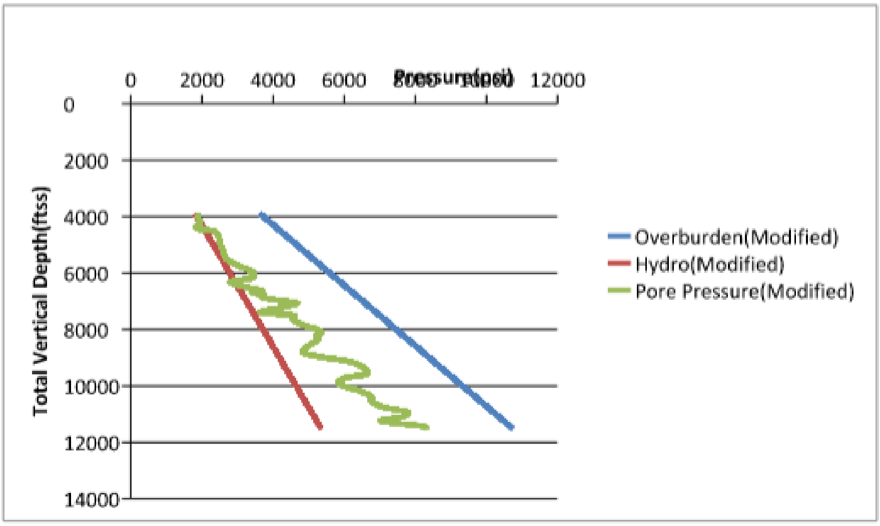


Figure 1.5a: Estimated Pore Pressure trend for Well 5 with Eaton's and Eaton's Modified Models

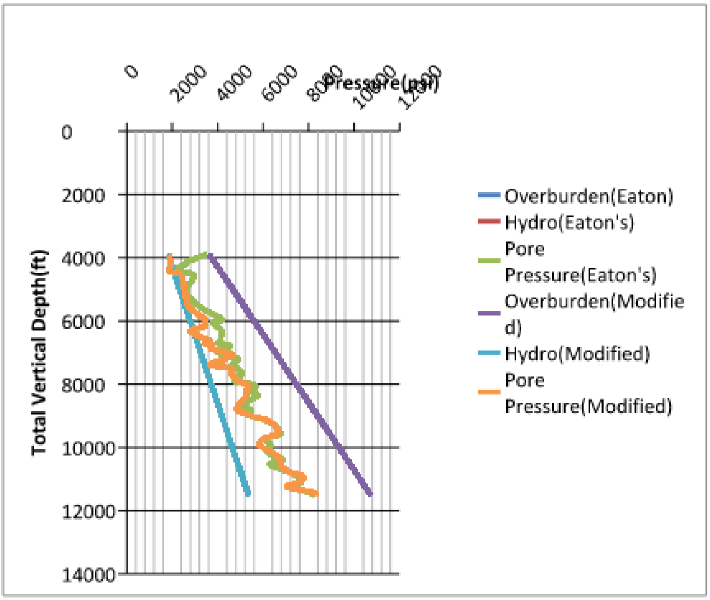


Figure 1.5b: Eaton's Modification and Eaton's Model Correlation for Pore Pressure Trend for Well 5

V. CONCLUSION

The integrated approach that coerce seismic and petrophysics used for the analysis of seismic and petrophysics data in the Niger-Delta revealed the overpressure depths overlying thin beds filled with hydrocarbons within the field examined. Porosity conditioning is taken into consideration a critical factor to a successful pressure profile analysis. This will require a seismic gathering, processing and interpretation techniques.

However. one of the areas that need some special attention in the industry as regards Pore Pressure Prediction is making available simple, efficient, reliable and fast empirical correlations or mathematical model(s) that could assist in the determination of subsurface reservoir overpressure which could also be easily validated with measurement while drilling(MWD) or Logging While Drilling(LWD) in addition with post drilling data which cut across a specified oil and gas field settings. Many best practices available in the oil and gas industry are being used as regards pore pressure predictions e.g Geophysics methods, Drilling parameters utilization, Petrophysics, Seismic and so.on. Though there as well many different empirical models which considers to an extent non- petrophysical data e.g Seismic.

This particular research work was credibly able to integrate an existing transit time dependent pore pressure prediction known as the Eaton's model to be applicable to an Offshore Niger Delta field evaluation of pore pressure. Thereafter, the research further developed a modified Eaton's model, theses are presented as a dimensionless equation in chart form.The results of pore pressure from the modified equation are then validated with a field data(Data that took into consideration seismic sections and well logs interpreted on PETREL Schlumberger's seismic well integration software) in a bid to confirm the applicability of such a model.

The pressure profile characterized with an abnormal pore change with depth that is pseudo parallel to the lithostatic(Overburden) pressure gradient from depth of 4091.62ftss to 8816.96ftss or rather in terms of pore pressure, i.e from pore pressure of 2739.233psi to 5911.3727psi. An abrupt or sudden break between 8329.4196ftss to 9093.09ftss with corresponding pore pressure from 6597.9738psi to 7500.019psi. This definitely indicates or explains possible presence of micro fractures which could have been caused by hydrocarbon generation or oil show.

Similarly in Well 5 , at depth of 11,421.53ftss which is the top of overpressure and the zone proceeds till 11,529.64ftss excepts at some points like 6328.05ftss, 7389.93ftss, 8646.43ftss and 9926.94ftss where there are abrupt breaks in formation pressure which indicates possible presence of micro fractures possibly catalyzed/ characterized by hydrocarbon generation.

Therefore, we can express a good correlation pressure values from the data and ease flow of evaluating the pore pressure which shows great correlation when compared with that of existing Eaton's model technique used for pressure prediction in the wells for the Niger Delta field X.

VI. RECOMMENDATION

The empirical derived model(Eaton's modified) clearly gives an excellent matching results with previous Eaton's equation model being used worldwide, that is conventional approach.

This research work undoubtedly explains the possibility of designing a model in form of either mathematical equation or chart correlation for application in estimating pore pressure prediction or detecting overpressure zone for a specified oil and gas basin .that is in this wise, Field X offshore Niger Delta basin.

It is expected that in future research work investigations, there will be need to take into consideration the power of seismically derived transform velocity (i.e Pre Stack Data conditioning) which could mostly be done on hybrid and super computers. This is because the interpretation presented on this research are only verifiable on the parameters of sonic transit time from well log and two way time from seismic sections. So therefore, there is need to subject field data to more rigorous pressing techniques of data conditioning that this research work quest to embark on in the nearest future. This will really improve the accuracy of obtainable results.