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Overpressure zone Detection/Pore pressure prediction in an offshore Niger Delta field using Drilling and Petrophysics parameters

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Abstract
It has been evaluated that over pressured matrix formations are identified with deep water Niger Delta basins given a normal average pressure gradient of 0.64psi/ft. Conventionally, a pressure gradient greater than this is known to be taken as an abnormal over pressured zone. This will then serve as a resource description in a log enhanced data/ information of a subsurface as a hydrocarbon prospective prediction / prediction evaluation.
In this study, the plot of depth against pore pressure from the depth of 2460 m at which parameters were taken were recorded to the depth of 3674m. Therefore, it should be observed that the pore pressure increased following a normal trend until it reaches a depth of 2975m where the deviation from the usual trends till it reaches a depth of 2975m where the deviation commenced, this trend therefore continues gradually till it reaches 3670m where a significant increase of pore pressure from 9.8ppg to 12.9ppg at 3674m was observed.

Keywords: Drilling, Petrophysics, Offshore, Pore pressure

1. Introduction

Background to the study

Observation as regards limitations to permeability which thus preventing pore pressure from achieving equilibrium cannot but be over emphasized.
Therefore, the technology involved or rather the technical science of predicting or deciphering the depths where over pressure takes place is over pressure detection phenomenon. Therefore, in any situation of drilling, detection of over pressure is prominent in pre drilling program.
Conventionally, overpressure/ pore pressure formations are usually encountered or do take place while drilling at various depths as regards variations of petro physics parameters which do usually pose threats to drilling operations such as the kicks (initial movement of reservoir fluid inside the wellbore), Blowouts (Uncontrollable kick) and other problems associated to drilling.
It has been established that an integral causes of over pressure, that is, abnormal pressure is as a result of under compaction of shale; the under compaction though as an aftermath of the inadequate expulsion of water or other fluid from shale during compaction which is as a result of the presence of pore pressure; a troubled effect zone for drilling, while blowouts may result if over pressure are not detected on time. The situation of this occurrence of problems are usually expensive and disastrous.
Therefore, it is so important to be aware of the danger of high-pressure zones i.e., overpressure zones and the geology/ geophysics/ petro physics of places where they may likely to take place.

Objectives of the research focus on

1. Determination of depth of the overpressure zone, using drilling parameters such as weight of Bit (WOB), Rotary speed, Rate of penetration.
2. Detection of overpressure zone using petrophysics parameters e.g., ‘DC’ Exponent, formation pressure and shale density.

The scope of this work is limited to the Data gathered at Nigeria Petroleum Development Commission Edo state, A subsidiary of NNPC. This work as well is limited with the application of drilling parameters.

Problem statement of the research

As a result of drilling problems emanating in oil and gas industry, such as well kick, Gas kick, Fire hazard and reservoir pressure blowout, which occur due to the reservoir pressure greater than the hydrostatics pressure at a predetermined depth.

Justification of the research

Due to the erratic pressure that always occur while drilling, well drilling designed is necessary where it is imperative to ensure there is relatively evaluation of pressure either normal, abnormal and subnormal pressure.

Pore Pressure/Overpressure driven seismic response

They are zones of thick Pleistocene-Miocene sediments which are identified as elastic rock which are poorly consolidated at the upper part of the segment lithology and are over pressured at the most to (Madatov, 2005).

Hydrodynamic phenomena have been ascribed to abnormal or anomalous pressures identified/encountered in oil wells (Neuzil, 1995).

Determination of pore pressures in many of the deep-water environments in the world with an appreciable success recorded in all fields examined (Traugott, 1997) [4].

In addition, seismic inversion system improved the resolution of the estimated velocity values but usually requires a reliable and dependable low frequency model and calibration. (Alao, 2014) [1]

The conversion of the estimates of reflection coefficients into a visual image of acoustic impedance with depth was discussed as a matter of procedure in detail by (lavergne and wiliams, 1997) [2], (Lindseth, 1979) and (Dobrin, 1988).

The confirmation of this generality observation is theoretically reproduced via effective medium modeling. This is a new tool for seismic pore pressure and pore fluid surveillance during well production as well as overpressure detection from seismic, cross well, log of sonic and measurement taken previous of the bit (Dvorkin, 2000).

The reflection wave method has been questionable due to; low sensitivity of the velocity derived overpressure response associated for consolidated elastic and carbonate rocks, there are limitations in seismic wave spatial natural resolutions. (Madatov, 2002).

Consequently, the investigation of overpressure been based on shale deformation behavior using resistivity, sonic logs, Spontaneous potential (SP) and gamma ray logs. (Alao, 2014) [1].

2. Methodology: **Case study**

Brief history of Oziengbe South-1

Tx field is an onshore well located South East of the Niger Basin in OPL421 concession.

The well is an exploratory well (vertical well) which was drilled with the objective of confirming the existence of hydrocarbon in Oziengbe field.

Data Aquisation

The data for TX Field was taken from a depth of 2,476m to the total depth of 3,674m. The data was obtained from mud logging in this case

Drilling parameters and petrophysics parameters used

i) Rate of penetration: The rate of penetration which is one of the leading parameters measured during drilling was simply noted by the driller as the time required to drill a foot of formation per hour.

ii) DC- Exponent: Dc-exponent is calculated by the use of computer. The following equation is used.

$$DC = \frac{d \times 90}{MW}$$

Where Dc = Corrected d- exponent

90 = Normal fluid gradient (ppg)

Or 0.465psi/ft

MW = Mud weight (ppg)

D = d-exponent

iii) Pore pressure: This parameter was calculated by using a designed software

iv) Total gas: Sample of unwashed cutting were taken and put in a stirrer of the blender type with a specific volume of water.

v) Flowline temperature

The flow line temperature was recorded with the aid of thermometric rod with a platinum

vi) Mud weight: The weight of the mud was determined using the mud balance

vii) Shale density: The shale density was determined by placing sample inside the liquid column having a density that varies with height, the sample from cuttings take up a position at level corresponding to their own density.

3. Result and discussion

Analysis of drilling parameters

Prior to the kick (initial movement of formation fluid into the well bore), drilling data parameters were taken and recorded from the depth of 2460m to a depth of 3674m. Plot are made of hole depth against the various drilling parameters used in the detection of overpressures in TX Field with the aid of these analysis the top of the transition zone (top of over pressures) and over-pressured zones were determined.

Rate of penetration

Drilling rate is a very useful tool in the detection of change in pore pressures, but it should be noted that, it is affected by lithology changes, bottom hole clearing, rotary speed, weight on bit and some other factors

In the plot of hole against Rate of penetration. It can be seen that the Rate of penetration decreases following a normal trend until at a depth of 2974m where there was a deviation from this trend. This depth could be referred to as the top of the pressure transition zone. The rate of penetration did not follow a normal decreasing trend, but rather a gradual increasing trend until the hard over pressure permeable zone was penetrated at a depth of 3674m.The plot of the hole depth against ROP for TX Field can be seen in fig 1.

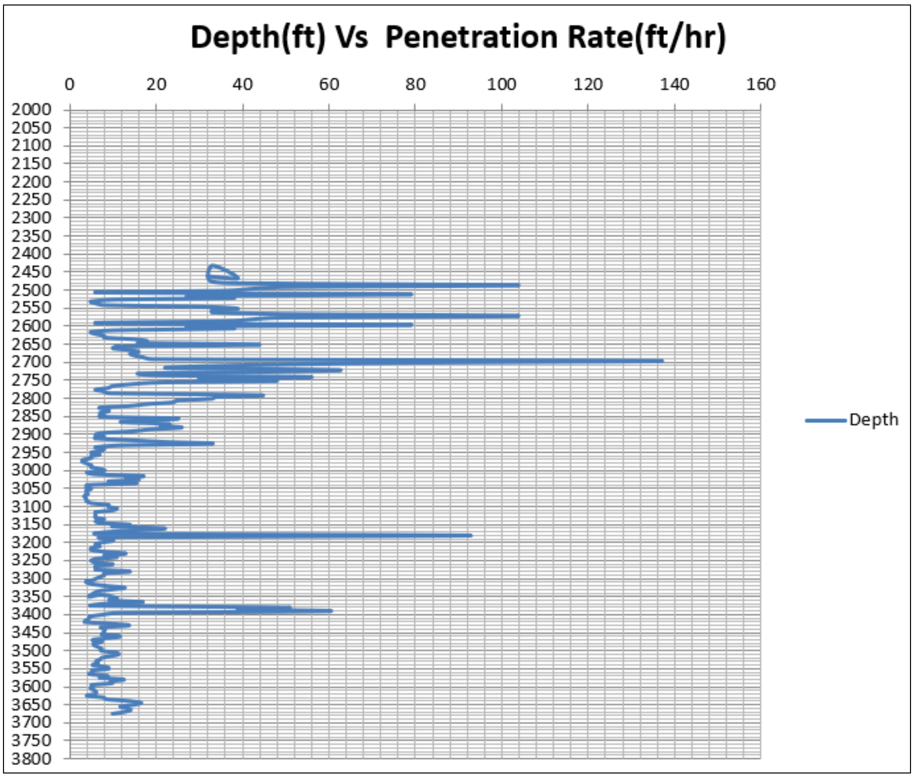

Fig 1: Plot of hole depth against ROP for the field

Table 1: Showing the data for drilling parameters TX field data

(Anormal Pressure Detection Data)									
Depth	Pen. Rate	WOB	RPM	MW	%Shale	De	De/c	Shale D	F.L Temp
2460	32	40	80	1.068	SD	1.55	1.45	2.32	136
2465	39	40	80	8.9	SD	1.48	1.39	2.32	136
2430	33	40	80	8.9	SD	1.54	1.44	2.32	136
2475	33	40	80	8.9	SD	1.54	1.44	2.32	136
2480	50	40	80	8.9	SD	1.36	1.28	2.32	136
2485	104	36	80	8.9	SD	1.14	1.07	2.32	136
2490	49	36	80	8.9	SD	1.37	1.28	2.35	137
2495	42	36	80	8.9	SD	1.42	1.33	2.35	137
2500	36	36	80	8.9	SD	1.46	1.37	2.35	137
2505	7	36	80	8.9	SD	1.95	1.83	2.35	138
2510	79	36	80	8.9	SD	1.23	1.15	2.35	138
2515	28	36	80	8.9	SD	1.54	1.44	2.36	139
2520	38	36	80	8.9	SD	1.48	1.38	2.36	139
2525	10	36	80	8.9	SD	1.84	1.73	2.36	140
2530	5	36	80	8.9	SD	2.05	1.92	2.37	141
2535	6	36	80	1.056	SD	1.65	1.57	2.37	124
2540	8	36	80	8.9	SD	1.58	1.5	2.36	126
2545	32	25	80	1.06	SD	1.69	1.58	2.32	128
2550	39	25	80	8.9	SD	1.64	1.53	2.37	429
2555	33	25	80	8.9	SD	1.56	1.36	2.36	130
2560	33	25	80	8.9	SD	1.22	1.14	SD	131
2565	50	25	80	8.9	SD	1.22	1.13	SD	131
2570	104	25	80	8.9	SD	1.2	1.13	SD	132
2575	49	25	80	8.9	SD	1.2	1.26	SD	133
2580	42	25	80	8.9	SD	1.35	1.26	SD	134
2585	36	25	80	8.9	SD	1.25	1.16	SD	135
2590	7	25	80	8.9	SD	1.24	1.44	2.37	135
2595	79	25	80	8.9	SD	1.54	1.61	2.37	136
2600	28	25	80	8.9	SD	1.72	1.55	2.37	137
2605	38	25	80	8.9	SD	1.69	1.61	2.36	139
2610	10	25	80	8.9	SD	1.72	1.61	2.38	140
2615	5	25	80	8.9	SD	1.69	1.58	2.37	140
2620	6	25	80	8.9	SD	1.72	1.61	2.37	141
2625	8	25	80	8.9	SD	1.72	1.61	2.67	141
2630	8	25	60	8.9	SD	1.62	1.54	2.67	137
3495	7.4	33	80	9.6	90	1.82	1.59	2.4	150

	Abnormal pressure detection data	
Depth	**Pore pressure**	**Total gas**
2460	8.33	0.16
2465	8.33	0.16
2470	8.33	0.16
2475	8.33	0.16
2480	8.33	0.16
2485	8.33	0.16
2490	8.33	0.16
2495	8.33	0.16
2500	8.33	0.16
2505	8.33	0.16
2510	8.33	0.16
2515	8.33	0.16
2520	8.33	0.16
2525	8.33	0.16
2530	8.33	0.2
2535	8.33	0.2
2540	8.33	0.22
2545	8.33	0.22
2550	8.33	0.22
2555	8.33	0.22
2560	8.33	0.22
2565	8.33	0.33
2570	8.33	0.33
2575	8.33	0.33
2580	8.33	0.33
2585	8.33	0.33
2590	8.33	0.33
2595	8.33	0.33
2500	8.33	0.33
2605	8.33	0.33
2610	8.33	0.33
2615	8.33	0.33
2620	8.33	0.33
2625	8.33	0.9
3430	9.2	5.17
3435	9.2	5.17

Interpretation of plot

In the interpretation of overpressure detection plot for the TX field. The first indication of pore pressure increase was at 2975m. The pore pressure steadily increased until the hard over pressured permeable zone was penetrated at a depth of 3674m with a pore pressure of 12.9ppg.

At the depth of 2975m, the point at which the first increase in pore pressure above normal was detected, which could be referred to as the top of the pressure transition zone. There was an increase in the total gas above normal, a decrease in Dc-exponent and a decrease in shale density. There was evidence in support of the increase in formation pressure above normal. This evidence was clearly observed throughout the interval above 2975m. The most reliable parameter used in the quantitative evaluation of pore pressure was the dc-exponene, the shale density was also another reliable parameter for the deviation it showed from normal trend when plotted against depth.

The continuous increase in gas levels –back-ground, trip and connection gases throughout the over pressured section was also a good indicator of the increase in pore pressure

A kick was taken at a depth of 2674m at this depth a sharp increase in pore pressure was experienced of 12.9ppg. At the same depth there was corresponding increase in flow line temperature above normal, trend, a decrease in shale density, and an increase in total gas and decrease in dc-exponent.

Pore pressure analysis

It is logical to assume the pore pressure increases with depth as overburden increase. However, the increases in pore pressure follow a normal trend and if at any point there is a deviation from this that is a jump in pore pressure, it should indicate an over pressured formation. In this case study the plot of hole depth against pore pressure from the depth of 2460m at which data/parameters were taken and recorded to the depth of 3674m.it should be noticed that the pore pressure increase followed a normal trend until at the depth of 2975m where the deviation from normal trend until at the depth of 2975m where the deviation from the normal trend started. This trend continued on gradual increases to a depth of 3650m where there was a significant increase of pore pressure from 9.8ppg to 12.9ppg at the depth of 3674m.

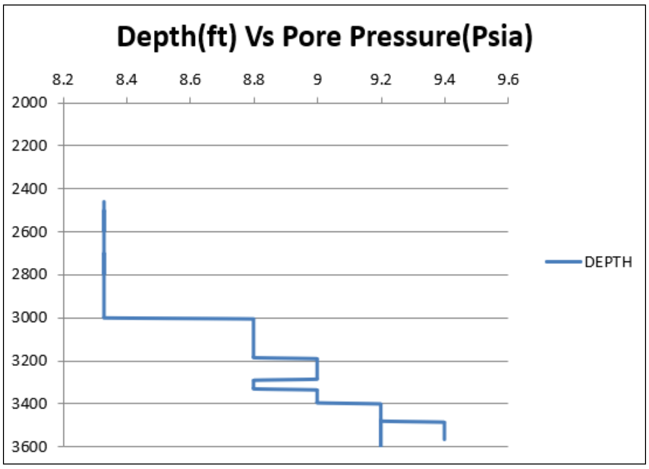

Fig 2: Plot of hole depth against pore pressure

Flow Line Temperature

Usually, the flow line temperature of drilling fluid, under conditions of uniform cooling, should increases regularly with depth, if the increase' deviates from the established pattern, it can be indication for the onset of over pressure fig 3 show a plot of hole against flow line temperature for TX Field.

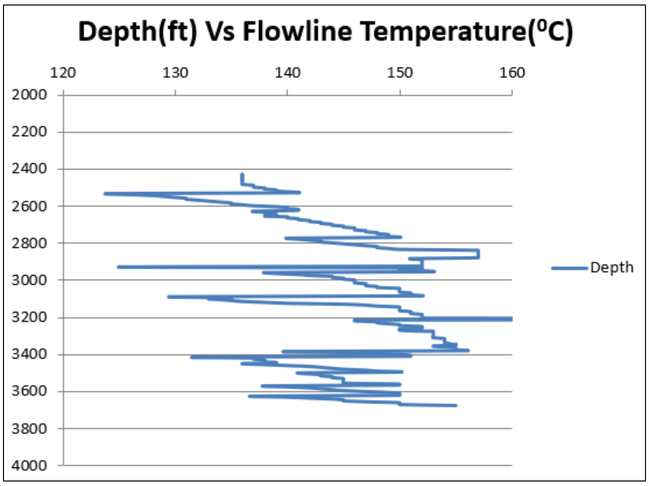

Fig 3: Depth (ft) vs flowline temperature

Interpretation of plot

Irrespective of the fact that it was said that any of the parameters recorded indicates overpressures, the various parameters must be correlated and if up two or three of them tally, an over pressured some can be confirmed.

In the interpretation of overpressure detection plot for TX Field a number of parameters were correlated. The parameters include rate of penetration, weight on bit, rotary speed, dc exponent, total gas, shale density, flow line temperature, pore pressure and mud weight.

The first indication of pore pressure increase was at 2975m, the pore pressure steadily increased until the hard overpressure permeable zone was penetrated at depth of 3674m with a pore pressure of 12.9ppg.

At the depth of 2975m, the point at which the first increases in pore pressure above normal was detected, which could be referred to as the top of the pressure transition zone. There was an increase in the total gas above normal, a decrease in dc- exponent and a decrease in shale density. These were evidence in support of the increase in formation pressure above normal. These evidences were clearly observed throughout the interval below 2975m.

The continuous increase in gas levels back ground, trip and connection gases throughout the over pressured section was also a good indicator of the increase in pore pressure.

A kick was taken at a depth of 2674m at this depth a sharp increase in pore pressure was experienced of 12.9ppg. At the same depth there was corresponding increases in flow line temperature above normal trend a decrease in shale density.

4. Conclusion

In this case study the plot of hole depth against pore pressure from the depth of 2460m at which data/parameters were taken and recorded to the depth of 3674m.it should be noticed that the pore pressure increase followed a normal trend until at the depth of 2975m where the deviation from normal trend until at the depth of 2975m where the deviation from the normal trend started. This trend continued on gradual increases to a depth of 3650m where there was a significant increase of pore pressure from 9.8ppg to 12.9ppg at the depth of 3674m.

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In Fig 4, it can be noticed as there is gradual decrease in shale density from 3000m, from this depth, the shale density plot takes a decreasing trend and the decrease was even much at the depth of 3674m where the kick was encountered.

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