Research Article Open Access CrossMark

Prediction of over pressured zones from well logs in the Niger delta

Abstract

The changes of some geophysical properties such as sonic compressional velocity with depth is an indication of the pressure system of over-pressured zones. Once these anomalous pressures are not forecasted correctly before drilling, calamitous occurrences, for instance kicks, and blowouts may ensue. This paper investigated the distribution and origin of overpressures in the Niger delta sedimentary basin using well log data. A Normal Compaction Trend line was generated by means of sonic velocity data and the overpressure zones were detected by observing the reversals of the sonic velocity data. The outcome of the formation pressure gradient prediction infers that the commencement of overpressure in the study area occurs at 7500ft with a resultant pressure gradient of 0.51psi/ft. Meanwhile, the findings of the assessment of sonic velocity and density cross-plots revealed disequilibrium compaction as the primary cause of overpressure. The prominent zones of overpressure were detected to appear at depths between 11100ft to 11300ft with an associated pressure gradient of 0.52psi/ft. to 0.53 psi/ft. This work will help in precisely predicting zones of overpressure in the research area prior to drilling.

Keywords: over-pressure, Niger delta, model, geophysical properties

Volume 5 Issue 2 - 2020

Abubakar Tanko,[1] Idris Danasabe Tanko,[2] Abubakar Bello[3]

Mineral and Petroleum Resources Engineering Department, Kaduna Polytechnic, Nigeria

Correspondence: Abubakar Tanko, Mineral and Petroleum Resources Engineering Department, Kaduna Polytechnic, Nigeria, Email abubakartanko87@gmail.com

Received: September 23, 2020 | **Published:** November 24, 2020

Introduction

Knowledge of pore pressure is crucial to virtually all facets of the oil and gas exploration to production activities. Overpressure is a term used to refer to any pressure in excess of hydrostatic pressure or it can also be referred to as a situation when the hydrostatic pressure exceeds its normal limit. The Recognition and estimation of over pressured formations are vital to exploration, drilling and production of hydrocarbons since oil and gas distribution is associated with regional and local subsurface pressures and temperatures. Information on the anticipated formation pressure and fracture gradients form the basis for the efficient drilling of wells, with correct mud densities, the proper engineering of casing programs and the proper completion's which must be effective, safe and allow for the killing of the well without excessive formation damage.[1,2]

Detection of Overpressured zones are conducted with the aid of well logs or velocities obtained from seismic surveys or even both Kumar and Ugwu. The physical basis for this has been the often-observed correlations between seismic velocity and porosity, and between porosity and effective pressure. The oil and gas industry has utilized several techniques for locating and estimating overpressures. Broadly the techniques can be classified into two: seismic measurements made before or while a well is drilled, and well logs obtained after the well has been drilled. The determination of porosity and formation pressures from seismic measurements has been of primary significance for many years.[3–5]

Abnormally high formation pressure zones are often associated with high porosities and low seismic velocities. Most methods require establishing a normal compaction trend versus depth of the formation properties to be established for the area of interest. Deviations from these normal trends are taken as indicators of overpressure, provided other conditions such as lithology remain the same. Well logs obtained after drilling are the most extensively usedand reliable means to construct rock models and delineate geopressures.[6–9] Formation pressure might occur between normal pressures to abnormal pressures. Normal pressures are known as hydrostatic pressures while abnormal pressure could be above normal pressure (overpressure) or below normal pressure (under-pressure). When the formation pressure of an area exceeds the hydrostatic pressure, the pressure is regarded as over-pressured. If the pore pressure falls below the normal pressure, it is regarded as under-pressured. The slowing of sonic-wave velocity (V_p) with increasing formation pressure has been the basis for overpressure detection and quantification in shales for several years. Normally, an increase in pore pressure (more accurately regarded as an increase in overpressure; the difference between the pore pressure and the hydrostatic (normal) pressure) as a result of unsuccessful fluid escape arrests compaction, leading to abnormally high porosity for a given depth of burial.

Methodology

The technique employed for the prognosis of the abnormally pressured environment was the use of well logs obtained from a neighboring well situated in the Niger Delta. Sonic compressional velocity was employed in constructing a Normal Compaction Trend line, which in turn was analyzed to identify reversals of the sonic velocity data which is symptomatic of an over-pressured area. Cross-plots of sonic velocity and density were also analyzed so as to ascertain the cause of overpressure in the study environment. Data used was obtained from Oriental energy and the analysis was conducted using RokDoc software.

Normal compaction trend (NCT)

The NCT was calculated to detect the over-pressured and normal pressure zones. The normal pressured line was determined using the sonic velocity log with the aid of the RokDoc software employing the reciprocal input log transform of compressional velocity, V_p.

$$\frac{1}{V_p(Z_{ml})} = \frac{1}{V_{pMatrix}} - \left(\frac{1}{V_{pMatrix}} - \frac{1}{V_{pTop}}\right) * e^{-b*zml} \quad (1)$$

Where V_{pTop} is the compressional sonic velocity at the surface (ft/s).

$V_{pMatrix}$ is the compressional sonic velocity at maximum extrapolated (ft/s),

b is the compaction coefficient (1.5 x 10^{-4} ft^{-1})

Lithostatic pressure

The lithostatic pressure was calculated from density log by taking the sum of weight of sediment at all depth. The overburden pressure was calculated by means of a model fit of the density log (Rho fit) by using the equation;

$$R_{ho}(Z_{ml}) = R_{hoMatrix} - (R_{hoMatrix} - R_{hoTop}) * \exp(-b * Z_{ml}) \quad (2)$$

Where $R_{ho}(Z_{ml})$ =density at depth z below ground surface (mudline).

$R_{hoMatrix}$ = density of matrix

R_{hoTop} = density at mudline (ground level)

b = Compaction coefficient (1.5 x 10^{-4} ft)

Formation pressure prognosis

The forecast of formation pressure was executed with the aid of Eaton's model. The model relates sonic velocity data to formation pressure by comparing sonic velocity in a normally compacted formation to its corresponding observed value.

$$P_p = P_{obs} - \left(P_{obs} - P_{hyd}\right) * \left(\frac{V_p}{V_n}\right)^3 \quad (3)$$

Where = forecasted formation pressure in psi.

P_{obs} = overbur P_p den pressure

P_{hyd} = hydrostatic pressure

Overpressure mechanism Investigation

The cause of overpressure was detected using velocity and density analysis. Cross-plot of shale velocity against density was employed to distinguish between overpressures generated by disequilibrium compaction and other mechanisms. The cross-plot of velocity against density was plotted using Rokdoc and analyzed by comparing them with the model by Hoesni so as to identify the signature and consequent cause of overpressure in the study area (Figure 1).[10]

Results and discussion

The generated normal compaction trend, lithostatic pressure, forecasted formation pressure and porosities are presented in table below.

Overpressure detection

Overpressure detection was executed by noting the deviations of the sonic compressional velocity data from the Normal Compaction Trend line. From the plot below, the compressional velocity log data represented by dark red dots, showed a reversal (i.e. decrease) from the established Normal Compaction Trendline, which is indicative of of an over pressured zone. The generated Normal Compaction Trend shows that the formation is normally pressured up to a depth of about 7500ft. (TVDml) where the inception of overpressure is encountered. Normal pressure is then noticed from about 7800ft to 11000ft. At a depth of 11100ft, an over-pressured zone is encountered up to the total depth. The sonic velocity data has a linear trend line, which is in keeping with the normal compaction trend line which brings to light the fact that formation pressure is normal in these formations. The reversal of the compressional velocity at the rear of the established normal-compaction trend line is suggestive of the overpressure zones. The computed formation pressure gradient also corroborates the results obtained from the reversals on the NCT with the onset of overpressure occurring at 7500ft with a corresponding formation pressure gradient of 0.51psi/ft. Normal formation pressure gradient of 0.45 psi/ft to 0.46psi/ft was noted between 7800ft to 11000ft. An overpressure zone with a formation pressure gradient of 0.52psi/ft was noted at 11100ft (Figure 2).[11–14]

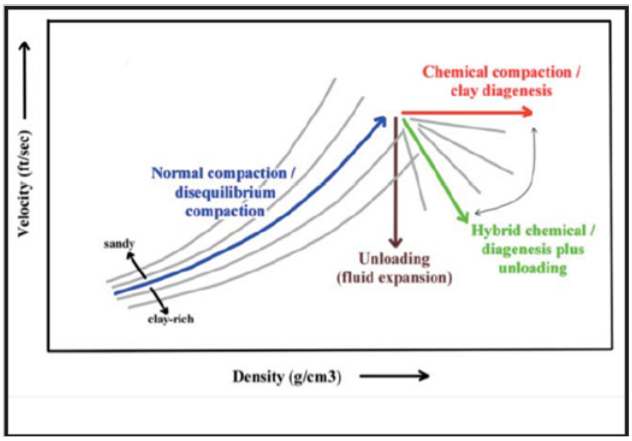

Figure 1 Velocity vs. Density signatures and their associated, causal mechanisms of overpressure generation.

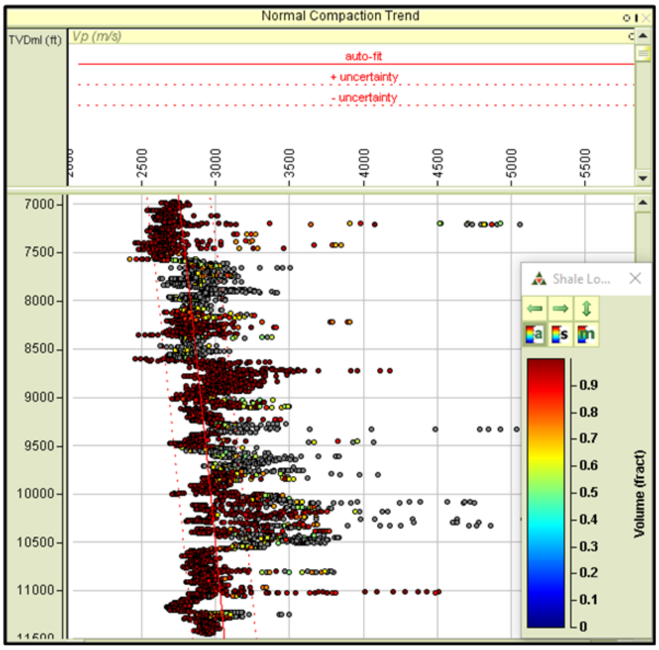

Figure 2 Generated Normal Compaction Trend.

Overpressure mechanism investigation

The Cross-plot of shale velocity against density shown below clearly depicts that the primary mechanism of overpressure in

Citation: Tanko A, Tanko ID, Bello A. Prediction of over pressured zones from well logs in the Niger delta. *Int J Petrochem Sci Eng.* 2020;5(2):62–65.
DOI: 10.15406/ipcse.2020.05.00123

the area is disequilibrium compaction as both sonic velocity and density increase together (Figure 3). More so, comparison of the signature generated by the cross-plot with Hoesni's model pinpoints disequilibrium compaction as the overwhelming cause of overpressure in the study area (Table 1).

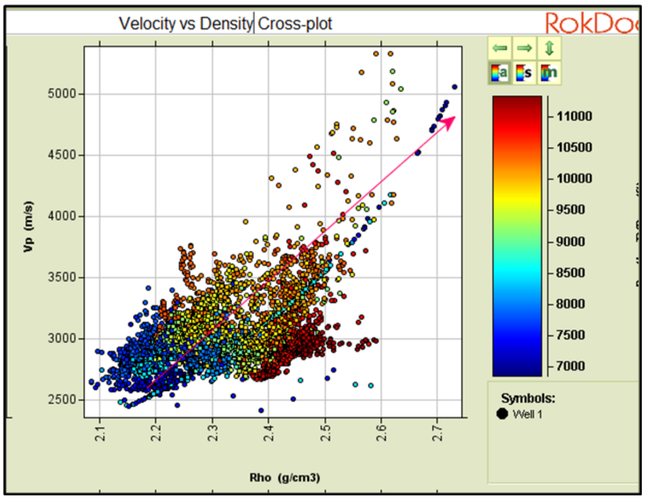

Figure 3 Cross plot of sonic velocity against density.

Table 1 Results of forecasted overpressure zones

Depth (ft)	Vp (m/s)	Vn (m/s)	Pres-litho (Psi)	Phyd (Psi)	PPP (psi)	PP grad (psi/ft)
6980.97	2710.85	2756.04	6115.32	3113.44	3258.71	0.47
7100.39	2706.44	2765.12	6231.75	3166.7	3357.76	0.47
7200.79	2778.04	2772.72	6330.4	3211.48	3193.49	0.44
7300.52	2701.71	2780.23	6428.18	3255.96	3517.21	0.48
7400.92	2692.97	2787.76	6525.55	3300.74	3618.61	0.49
7500.66	2660.28	2795.2	6622.88	3345.22	3797.28	0.51
7600.39	2647.33	2802.6	6718.97	3389.7	3912.97	0.51
7700.79	2679.35	2810.02	6815.35	3434.47	3884.52	0.5
7800.52	2730.47	2817.35	6910.24	3478.96	3786.71	0.49
7900.92	2785.59	2824.69	7005.05	3523.73	3666.3	0.46
8000.66	2828.39	2831.95	7100	3568.21	3581.52	0.45
8100.39	2844.09	2839.17	7198.58	3612.69	3594.01	0.44
8200.79	2867.55	2846.4	7298.84	3657.47	3575.72	0.44
8300.52	2854.53	2853.55	7399.21	3701.95	3698.16	0.45
8400.92	2847.5	2860.71	7499.52	3746.73	3798.47	0.45
8500.66	2903.6	2867.78	7595.37	3791.21	3646.88	0.43
8600.39	2942.05	2874.82	7691.26	3835.69	3558.82	0.41
8700.79	3077.69	2881.87	7792.92	3880.46	3027.48	0.35
8800.52	3077.71	2888.83	7896.76	3924.95	3093.85	0.35
8900.92	3027.1	2895.8	8000.56	3969.72	3396.18	0.38
9000.66	2976.65	2902.69	8101.78	4014.2	3693.73	0.41

Table continue

Depth (ft)	Vp (m/s)	Vn (m/s)	Pres-litho (Psi)	Phyd (Psi)	PPP (psi)	PP grad (psi/ft)
9100.39	2985.83	2909.54	8203.8	4058.68	3723.98	0.41
9200.79	2950.2	2916.4	8304.92	4103.46	3955.67	0.43
9300.52	2972.92	2923.17	8404.99	4147.94	3926.87	0.42
9400.92	2892.24	2929.96	8506.5	4192.72	4357.15	0.46
9500.66	2881.59	2936.66	8609.48	4237.2	4478.57	0.47
9600.39	2930.05	2943.32	8707.26	4281.68	4341.27	0.45
9700.79	3024.94	2949.99	8807.35	4326.45	3976.18	0.41
9800.52	3052.21	2956.58	8907.03	4370.94	3916.39	0.4
9900.92	3026.23	2963.17	9009.94	4415.71	4116.11	0.42
10000.66	3090.58	2969.68	9113.4	4460.19	3868.44	0.39
10100.39	3137.2	2976.16	9216.96	4504.67	3697.58	0.37
10200.79	3207.24	2982.64	9322.1	4549.45	3388.05	0.33
10300.52	3156.77	2989.04	9427.48	4593.93	3733.72	0.36
10400.92	3124.57	2995.44	9532.24	4638.71	3978.16	0.38
10500.66	3011.34	3001.77	9634.5	4683.19	4635.66	0.44
10600.39	2936.29	3008.05	9734.92	4727.67	5077.58	0.48
10700.79	2920.47	3014.34	9840.26	4772.44	5231.33	0.49
10800.52	2963.08	3020.55	9945.04	4816.93	5104.14	0.47
10900.92	2962.7	3026.77	10050.8	4861.7	5184.28	0.48
11000.66	3023.68	3032.86	10156.26	4906.18	4953.75	0.45
11100.39	2880.77	3045.1	10261.77	4950.66	5764.95	0.52
11200.79	2849.61	3051.13	10366.37	4995.44	5990.89	0.53
11300.52	2912.35	3057.15	10472	5039.92	5775.79	0.51

Conclusion

The work entailed the detection of zones of overpressure and subsequent identification of the causal mechanism of overpressure using well logs from an offshore well in the Niger Delta. The approach employed involved generating a Normal Compaction Trend using sonic velocity and noting areas of reversal of the sonic velocity data as the overpressure zones. Furthermore, forecasts of the formation pressure were conducted using Eaton's model and the formation pressure gradient was computed to validate the results of the NCT. The results of the formation pressure gradient imply that the beginning of overpressure in the study area occurs at 7500ft with a corresponding pressure gradient of 0.51psi/ft, while the analysis of cross-plot of sonic velocity with density revealed disequilibrium compaction as the cause of overpressure in the area. The highest zones of overpressure were observed to occur at depths between 11100ft to 11300ft with an accompanying pressure gradient of 0.52psi/ft to 0.53 psi/ft. This work will help in accurately predicting zones of overpressure in the study area prior to drilling.

Acknowledgements

None.

Conflicts of interest

There are no conflicts of interest.

Funding

None.

References

1. Athy L. Density, pororsity, and compaction of sedimentary rocks. *AAPG Bulletin*. 1930. p. 1–24.
2. G Bowers, T John Katsube. The role of shale pore structure on sensitivity of wire-line logs to overpressure. AAPG, Tulsa, Memoir. 2002;1:43–60.
3. Satinder Chopra, Alan Huffman. Velocity determination for pore pressure prediction. *CSEG Recorder*. 2006;31(4):9–46.
4. Peter R Cobbold, Benjamin J Clarke, Helge Løseth. Structural consequences of fluid overpressure and seepage forces in the outer thrust belt of the Niger Delta. *Petroleum Geoscience.* 2009;15(1):3–15.
5. Eaton B. The equation for geopressure prediction from well logs. *SPE.* 1975. 5544 p.
6. Goulty NR, AM Ramdhan, SJ Jones. Chemical compaction of mudrocks in the presence of overpressure. *Petroleum Geoscience*. 2012;18(4):471–479.
7. Green S. Pressure prediction module and pore pressure calculator. Rok Doc Training Manual. 2010.
8. Hottman C. Estimation of formation pressure from log derived shale. *Journal of Petroleum Technology.* 1965;17(6):717–722.
9. Katahara K. Overpressure and shale properties: stress unloading or smectite-illite transformation. 76th SEG Annual Meeting. *Expanded Abstracts*. 2006;1520–1524.
10. RW Lahann, RE Swarbrick. Overpressure generation by load transfer following shale framework weakening due to smectite diagenesis. *Geofluids*. 2011.
11. Richard E Swarbrick, Mark J Osborne, et al. Comparison of overpressure magnitude resulting from the main generating mechanisms. AAPG, Tulsa. 2002;76:1–12.
12. Tanko A. Development of an Appropriate Model for predicting Pore Pressure in Niger delta, Nigeria using Offset well data. International *Journal of Petrochemistry and Research*. 2019;274–279.
13. Terzaghi K. Theoretical soil mechanics. John Wiley and Sons, Inc. 1943.
14. Yoshida CA. An Investigative Study of Recent Technologies Used for Prediction, Detection, and Evaluation of Abnormal Formation Pressure in North and South America. *Society of Petroleum Engineers Paper*. 1996.

Citation: Tanko A, Tanko ID, Bello A. Prediction of over pressured zones from well logs in the Niger delta. *Int J Petrochem Sci Eng.* 2020;5(2):62–65. DOI: 10.15406/ipcse.2020.05.00123