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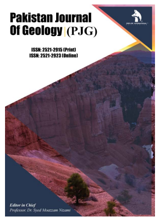

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RESEARCH ARTICLE

PREDICTION OF OVERPRESSURE FROM POROSITY ESTIMATION IN SEDIMENTARY ROCK FORMATION IN WESTERN NIGER DELTA, NIGERIA

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ABSTRACT

Overpressure prediction is vital for safety during exploration and drilling activities. Porosity indicates the potentiality or fluid storage capacity of rocks. It is the first among essential attributes of a reservoir. This study is aimed at predicting overpressure from porosity estimation in sedimentary formation and was carried out using well log data comprising of gamma ray, density and sonic logs from two exploratory wells in Niger Delta. Gamma ray log was used to delineate the lithology of the sedimentary sequence into sandstone and shale beds at the pre-determined depth intervals, porosity was estimated from interval transit time obtained using sonic log while overpressure was estimated using empirical relation. The results of this study show that porosity decreases with for both sandstone and shale beds, but however, porosity inversion was observed between the depth range of 2100ft and 3171ft. Overpressure zone was detected at the depth range of 2195ft and 3200ft at porosity value from 28% to 32% and 22% to 31% for sandstone and shale bed respectively. The knowledge of this study can be applied in the prevention of drilling activity hazards (blow out and lost circulation) and sedimentary basin analysis.

KEYWORDS

Overpressure zone, Sedimentary rocks, Lithology, Reservoir, Uncompaction

1. INTRODUCTION

Sedimentary rocks are known to be the most important type of rock to the petroleum industries and hydrocarbon exploration companies because most oil and gas accumulations occur in them, thus they are all petroleum source rocks. The movement of hydrocarbon (petroleum) in an ascending pattern (upward direction) through porous rocks gives rise to the occurrence of this petroleum rich reservoirs (Halliburton, 2001). Major accumulation of hydrocarbon characteristically occurs in sedimentary rocks (sand stones and lime stones) and are totally enclosed above, below and lateral by impermeable rocks called seal. Continuous deposition of sediments in the basin leads to deeper burial, which imposes an increase in temperature and pressure on the organic matter (called Kerogen) mixed with fine-grained sediments (Selley, 1998).

Over the years, complexities of reservoirs have increased, therefore the necessity for reduced uncertainty and inefficiency has turned out to be essential in order to guarantee that important data about the reservoir is obtained.

In the investigation and advancement of oil, formation evaluation determines the capacity of a well to create hydrocarbon. It is a strategy for recognizing commercial wells once they are penetrated. The issue in formation evaluation involves noting two legitimate questions; what the values for porosity and permeability that are take into consideration valuable generation from a specific development. The petroleum geologist must remain concentrated on the porosity and permeability of a formation; this can without much of a stress be accomplished by gauge of permeability and porosity. It is of great importance to accurately evaluate these parameters of a field; these parameters of a rock are a standout amongst the most vital parameters. Subsequently, careful understanding of its distribution in the reservoir is critical for precise production performance forecast. In petroleum exploration, the effects of overpressure can be desirable in the sense that they encourage hydrocarbon migration. They can also reinforce the efficiency of the sea land thus protect the accumulation (Bridges and Leon, 2020).

Sometimes, drilling for the exploration of hydrocarbon may sustain heavy losses in both human and financial terms due to lack or incomplete knowledge of pressure of the formation (Hossain and Islam, 2018). Porosity indicates the potentiality or fluid storage capacity of ricks, it is first of the two essential attributes of a reservoirs, it also defines the measure of void or pore space in works (DJebbar and Erle, 2016). In the world's sedimentary basins, overpressure zones are associated with permeability barriers, diagnosis, basin structure, uncompact ion and tectonism among others (Hiller,1991). In the Niger Delta Basin, the very rapid deposition of Akata shale on the top of the basement has a sealing impact on the pore or void spaces of shale.

This sealing impact ceases the vertical flow of fluids, this in turn creates or causes the formation to be under compacted and building of abnormal high-pressure zones (Bruce, 1973). The mechanisms, structure and level of pressure building or development in a rock fluid system vary significantly, and the variation depends on the basin history, geological structure, thickness and rock composition of the sedimentary section and activity of the geodynamic processes. In drilling operation, it is very necessary and important to determine the pressure of the various formations penetrated by the borehole. This enables the drillers take extra precautions while penetrating abnormally high-pressure zones in order to avoid damages, including fatalities due to blow outs (Nfor and Okolie, 2011).

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2. Study Area

The study area is within Edo State, onshore Niger Delta region of Nigeria. Figure 1 shows the map of the study area. The area is geological characterized by deposit laid during the tertiary and the Cretaceous period, the various formations are the Benin, Bende-Ameki, Ogwashi-Asaba, Imo, Nsukka formation (Reyment, 1965). The area is underlain by sedimentary rock with 90 percent sandstone and shale intercalation.

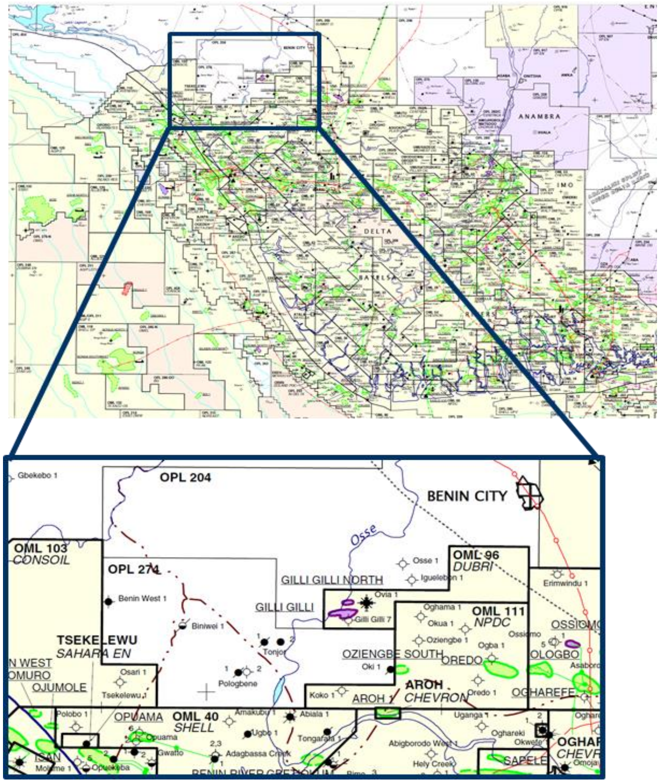

Figure 1: Map of the Study Area

3. Materials and Method

3.1 Materials

The materials used for this research are a suite of geophysical well log comprising of gamma ray, sonic and density logs as well as Microsoft excel spread sheet and petrel software.

3.2 Methods

Two exploratory wells (IDAMA 1 and IDAMA 2) within the study area were considered for this study, well log data in Log Ascii Standard (LAS) format, obtained within the study area from which porosity, velocity and transit time values were computed at various depth interval. Four stages are involved in the method used for this study as shown Figure 2 and are discussed under the following sub-headings.

3.2.1 Lithology Estimation

Gamma ray log was used to delineate the lithology of the sedimentary sequence into sandstone and shale beds at the pre-determined depth intervals. The gamma ray log in American petroleum institute (API) unit ranges from 0 at sandstone line to 150 shale line. As the signature of the log move towards the higher values, the formation becomes more shaly, whereas, as it moves towards the lower value, the formation becomes more sandy. The percentage volume of shale and sandstone were estimation using the following equations.

3.2.2 Porosity Estimation

Sonic log was digitized to obtain the transit time from which porosity was estimated using the following empirical relation according to (Schlumberger, 1989):

$$\phi_{sonic} = 0.625\left(1 - \frac{\Delta t_{mat}}{\Delta t_{log}}\right) \quad (1)$$

Where

ϕ_{sonic} = Sonic log derived porosity

Δt_{mat} = transit time of rock matrix (μs/ft)

Δt_{log} = transit time read from the log (μs/ft)

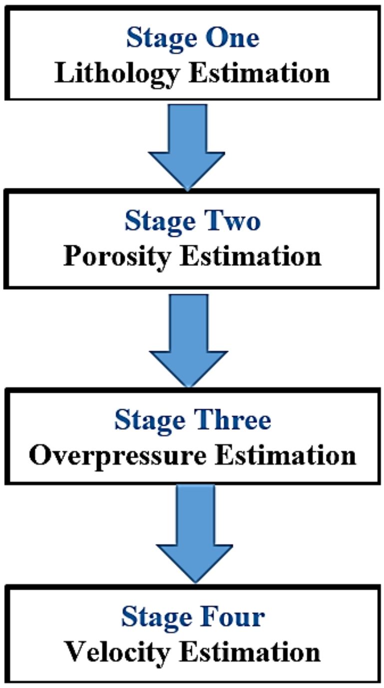

Figure 2: Four Stages of the Method Used

3.2.3 Overpressure Estimation

Overpressure values were estimated using the empirical relation according to Knut, (2010)

$$P = \rho g z \quad (2)$$

Where P = Overpressure value

ρ = Density of rock

g = Acceleration due to gravity

z = Depth of burial of rock

3.2.4 Velocity Estimation

Acoustic velocity was estimated by taking the reciprocal of the transit time read directly from the sonic log and is given by:

$$V = \frac{1}{\Delta t_{log}} \quad (3)$$

Where V = Acoustic velocity (m/s)

Δt_{log} = transit time read from the log (μs/ft)

4. Results and Discussion

4.1 Results

4.1.1 Data Presentation

The results of the parameters (transmit time, porosity, overpressure and velocity values) estimated at various depths for sandstone and shale beds of well IDAMA 1are presented in Tables 1 and 2 respectively whereas those estimated for well IDAMA 2 are presented in Table 3 and 4 for sandstone and shale beds respectively.

4.1.2 Analysis of Cross plots

The cross plots (graphs) of porosity versus overpressure, porosity versus depth and depth versus overpressure for both sandstone and shale beds of the two wells are shown in Figures 3 to 14

Table 1: Depth, Transit time, Velocity, Overpressure and Porosity of Sandstone Bed of Well IDAMA 1

S/N	Depth (ft)	Interval Transit Time Δt (µs/ft)	Velocity (ft/ µs)	Porosity (%)	Overpressure (psi)
1	1431	136	7.35	37	4217.53
2	1463	125	8.00	35	4206.09
3	1544	118	8.47	33	4111.19
4	1725	110	9.09	31	4523.65
5	1876	100	10.00	28	4706.87
6	2001	105	9.52	29	4549.45
7	2150	103	9.71	29	5289.98
8	2237	95	10.53	26	5620.79
9	2323	95	10.53	26	5697.10
10	2434	95	10.53	26	5860.87
11	2548	92	10.87	25	6010.56
12	2704	90	11.11	24	6023.01
13	2835	85	11.76	22	6281.84
14	2996	90	11.11	24	6516.30
15	3048	87	11.49	23	6412.77
16	3171	82	12.20	20	6620.13
17	3200	85	11.76	22	6793.17

Table 2: Depth, Transit time, Velocity, Overpressure and Porosity of Shale Bed of Well IDAMA 1

S/N	Depth (ft)	Interval Transit Time Δt (µs/ft)	Velocity (ft/ µs)	Porosity (%)	Overpressure (psi)
1	1408	120	8.33	34	4103.62
2	1415	125	8.00	35	4206.09
3	1454	126	7.94	35	4111.19
4	1484	105	9.52	29	4217.53
5	1524	120	8.33	34	4706.87
6	1609	120	8.33	34	4549.45
7	1655	110	9.09	31	5039.48
8	1695	105	9.52	29	5062.97
9	1771	100	10.00	28	5289.98
10	1865	105	9.52	29	5273.29
11	1871	100	10.00	28	5697.10
12	1978	110	9.09	31	6023.01
13	2063	100	10.00	28	6281.84
14	2100	100	10.00	28	6516.30
15	2106	100	10.00	28	6412.77

Table 3: Depth, Transit time, Velocity, Overpressure and Porosity of Sandstone beds of Well IDAMA 2

S/N	Depth (ft)	Interval Transit Time Δt (µs/ft)	Velocity (ft/ µs)	Porosity (%)	Overpressure (psi)
1	461	145	6.90	39	3962.54
2	466	150	6.67	39	4011.10
3	496	150	6.67	39	4163.82
4	655	135	7.41	37	4200.15
5	750	140	7.14	38	4217.53
6	833	135	7.41	37	4200.10
7	941	130	7.69	36	4178.16
8	988	125	8.00	35	4356.39
9	1067	120	8.33	34	4706.87
10	1103	125	8.00	35	4103.62
11	1175	120	8.33	34	4217.53
12	1237	120	8.33	34	4460.27
13	1271	120	8.33	34	4598.46
14	1387	112	8.93	32	4978.87
15	1463	110	9.09	31	5039.48
16	1551	110	9.09	31	5062.97
17	1603	110	9.09	31	6683.78
18	1698	105	9.52	29	7748.51
19	1825	98	10.20	27	7856.97
20	1966	95	10.53	26	7428.27
21	2017	95	10.53	26	9448.20
22	2067	90	11.11	24	9331.88
23	2195	95	10.53	26	9480.68

Table 4: Depth, Transit time, Velocity, Overpressure and Porosity of Shale beds of Well IDAMA 2

S/N	Depth (ft)	Interval Transit Time Δt (µs/ft)	Velocity (ft/µs)	Porosity (%)	Overpressure (psi)
1	1139	125	8.00	35	4217.53
2	1292	115	8.70	32	4200.10
3	1341	130	7.69	36	4111.19
4	1426	120	8.33	34	4356.39
5	1496	105	9.52	29	4706.87
6	1524	120	8.33	34	4103.62
7	1617	110	9.09	31	5039.48
8	1662	100	10.00	28	5062.97
9	1770	120	8.33	34	5289.98
10	1795	115	8.70	32	5273.29
11	1865	110	9.09	31	5697.19
12	1990	95	10.53	26	6023.01
13	2030	100	10.00	28	6281.84
14	2154	87	11.49	23	6516.30
15	2251	85	11.76	22	6683.78
16	2295	90	11.11	24	7748.51
17	2376	85	11.76	22	7856.97
18	2410	90	11.11	24	7428.27
19	2890	85	11.76	22	9448.20
20	2924	85	11.76	22	9331.88
21	2991	85	11.76	22	9480.68
22	3093	80	12.50	19	9905.11

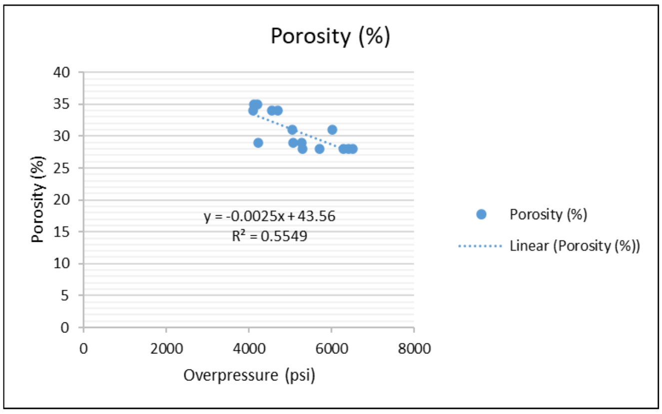

Figure 3: Porosity vs Overpressure for Sandstone bed of Well IDAMA 1

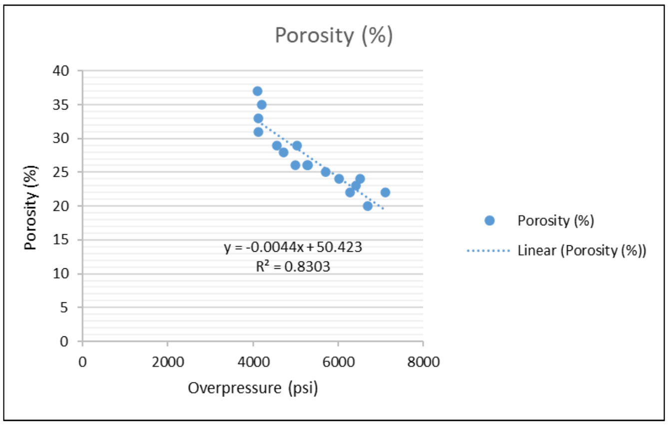

Figure 4: Porosity vs Overpressure for Shale bed of Well IDAMA 1

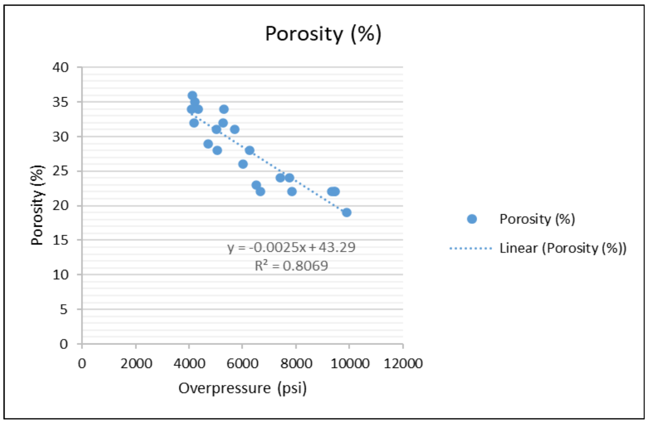

Figure 5: Porosity vs Overpressure for Sandstone bed of Well IDAMA 2

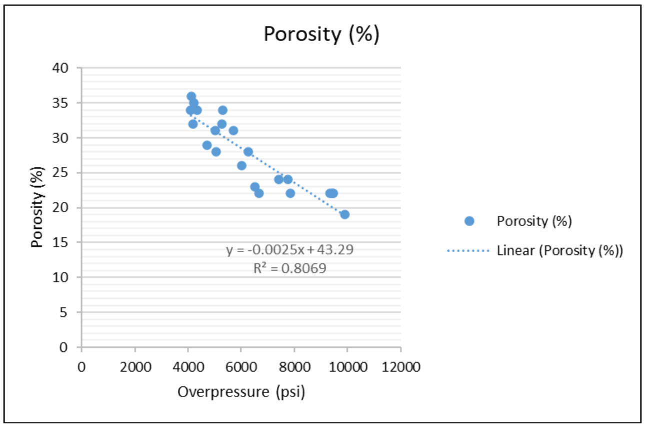

Figure 6: Porosity vs Overpressure for Shale bed of Well IDAMA 2

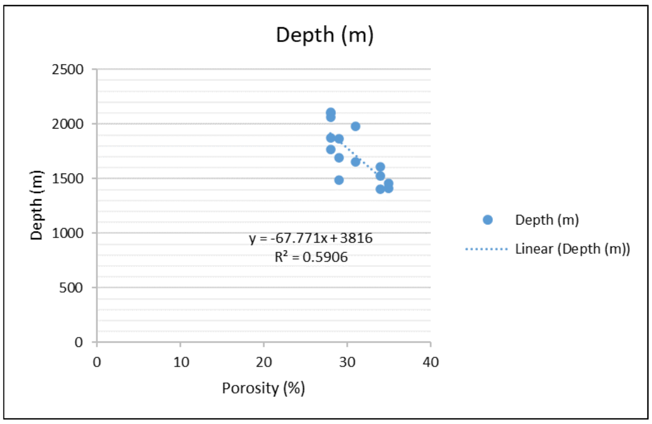

Figure 7: Depth vs Porosity for Sandstone bed of Well 1

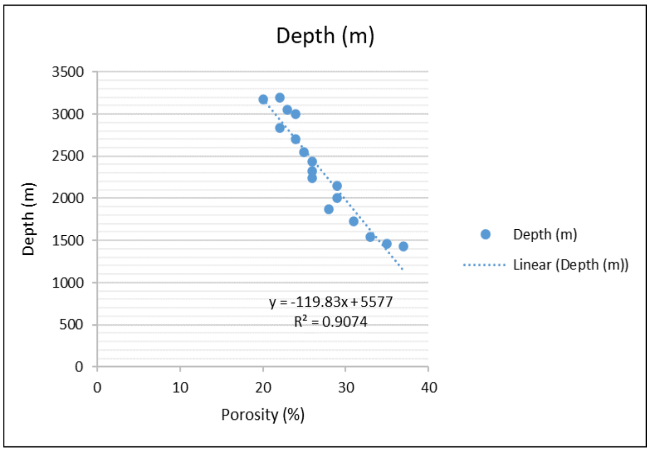

Figure 8: Depth vs Porosity for Shale bed of Well 1

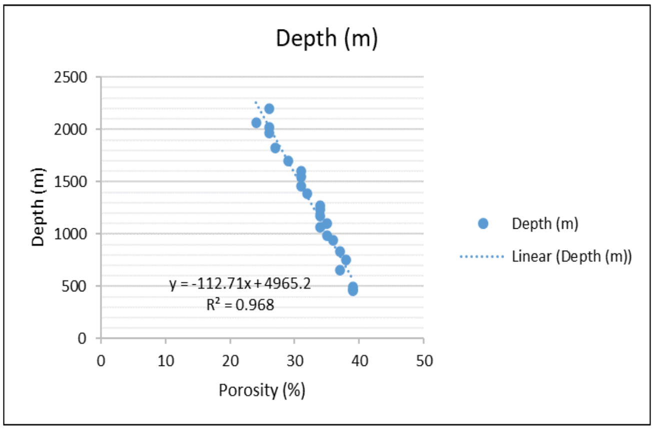

Figure 9: Depth vs Porosity for Sandstone bed of Well 2

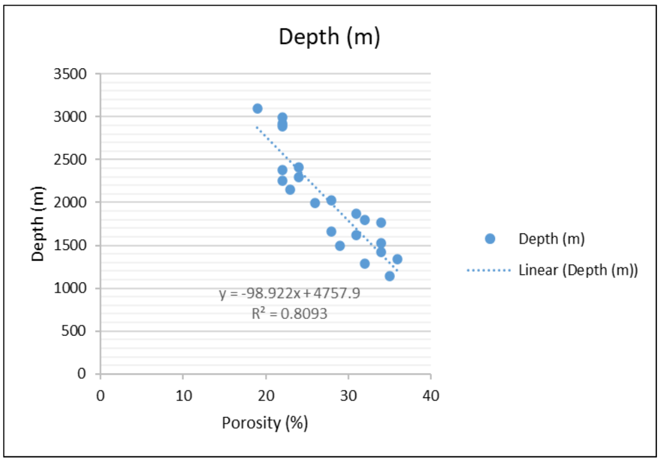

Figure 10: Depth vs Porosity for Shale bed of Well 2

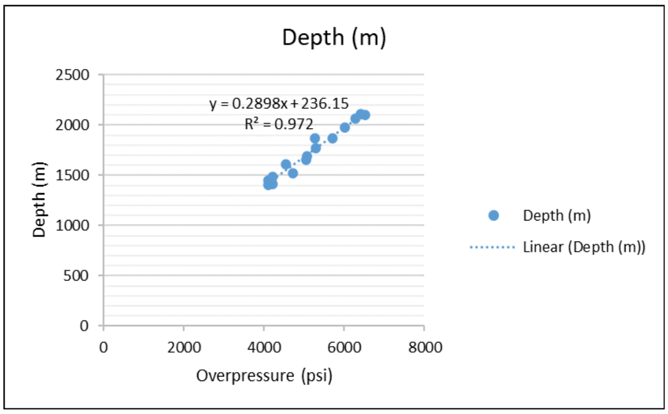

Figure 11: Depth vs Overpressure for Sandstone bed of Well 1

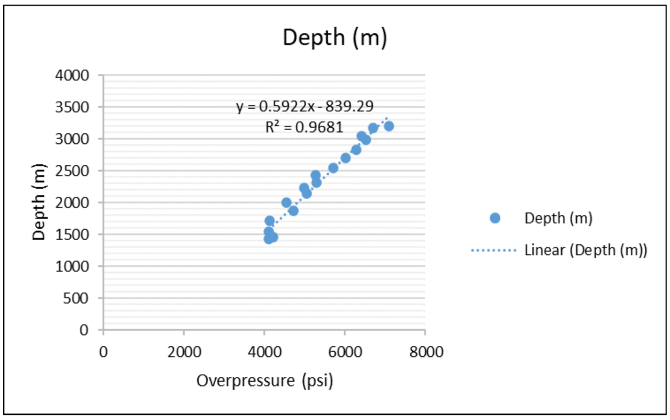

Figure 12: Depth vs Overpressure for Shale bed of Well 1

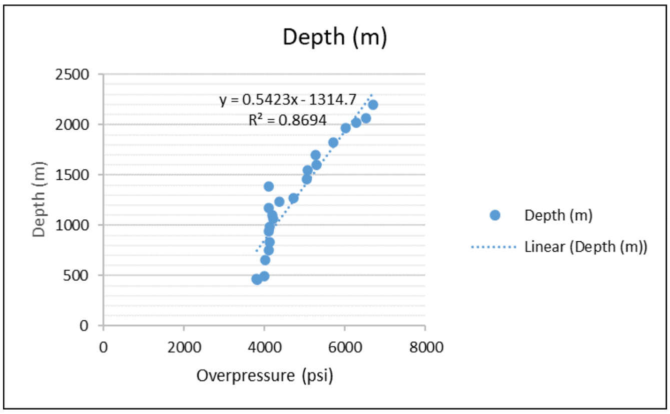

Figure 13: Depth vs Overpressure for Sandstone bed of Well 2

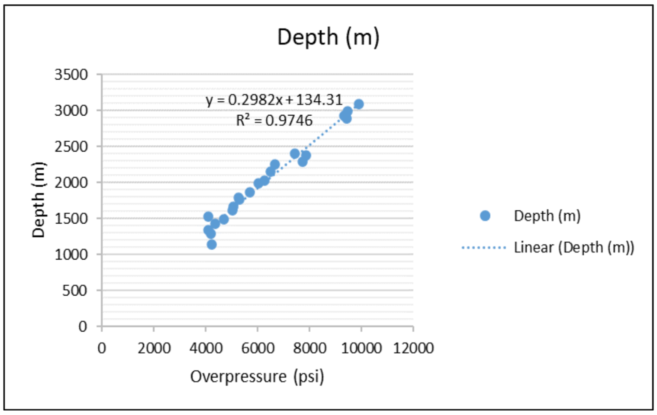

Figure 14: Depth vs Overpressure for Shale bed of Well 2

4.2 Discussion

4.2.1 Porosity versus Overpressure

It is observed from Figures 3 – 6 that there is general porosity decrease as overpressure increases in both sandstone and shale beds for IDAMA well 1 and IDAMA well 2. This can be attributed to compaction resulting from weight of overlying sediments because the deeper the formation, the more pressure from overburden which causes compaction of the formation and reduction in porosity.

4.2.2 Depth versus Porosity

There is a normal porosity decrease as depth increases for both sandstone and shale beds in the two wells. However, porosity inversion was observed between the depth range of 2100ft and 3171ft in the wells as depth increases, this can be attributed to under-compaction of overlying rocks as shown from Figures 7 to 10.

4.2.3 Depth versus Overpressure

Figures 11 to 14 show that there is a linear increase in overpressure with depth for both sandstone and shale beds in both wells IDAMA 1 and IDADMA 2. This is ideal since the deeper the depth of burial, the higher the confining overburden pressure and this shows that the formation is well compacted.

5. Conclusion

In this study, porosity is presented as an alternative indicator for overpressure zone in the area of study (Niger Delta). This method is more precise, can easily be applied and is even more economical.

From the results of this study, the following conclusions are reached:

i. Porosity is controlled by depth of burial and age of sediment.

ii. Overpressure increases with depth in sedimentary formations.

iii. Porosity decreases with increasing depth in normal compacted sandstone and shale beds or formations.

iv. Overpressure increases in both sandstone and shale beds as porosity decreases.

v. There is a linear increase in overpressure as porosity decreases in sedimentary formation.

vi. In general, can be predicted from porosity values in sedimentary formation.

Acknowledgement

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