Characterization of Over Pressured Zones in Emeabiam-Apani-Okwukwe-Iheoma-Alaoma Parts of Eastern Niger Delta, Nigeria

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Abstract: ***The Eastern Niger Delta has unique structural faults mapped as moderate relief East-West trending fourway dip closed anticline at both shallow and deeper levels downthrown to the first major E-W trending structure of IHEOMA structure. The OKWUKWE-1 well crossed a minor fault into shale and penetrated 350ft of the shale before problems of abnormal increase of pressures persisted and led to abandonment. The large thickness represented high rate of sediment supply impaired with low permeability that prevented the sediment from dewatering at the rate quick enough to allow hydrostatic pressure equilibrium hence, overpressure. Heavy gases appeared from the depths of 6760ft, which showed up as indicators of abnormally pressured zone. The Eastern Niger Delta has a trend of deposition of thick sediments with litho-stratigraphic units of Benin Formation, Agbada Formation and the underlying Akata Shale, which originated respectively from paleocontinental, transitional and marine environments composed of shales and marine clays. Some wells in this part of Eastern Niger Delta have pore pressure regime that resulted into overpressure conditions requiring increase of circulating mud weights. Some wells manifested sediments-transition and changes in Agbada Formation sequence of sand and shale transforming to continuous columns of shale. This is the measure of the degree to which pore fluid pressure significantly exceeded the predicted from the normal compaction of sediments with depth. Abnormal gas composition in the shale columns points to highly over-pressured zones.***

Keywords: Eastern part of Niger Delta, Overpressured zones, Pore pressure, undercompaction of shales, Agbada Formation, Akatashales and marine clays

1. Introduction

In an event of the inability of pore fluids to escape at a rate which allows equilibration with a Column of static water connected to the surface, yields an overpressure as Swarbrick (2003).Overpressure conditions were found to occur while drilling some wells in some fields of eastern part of Niger delta. Suchoccurred uniquely at certain depths of wells which were not deep enough to suggest entry into the AkataShales. Some overpressures can be ascribed to under compaction of shale sediments of considerable thickness ranging from 100ft to 400ft in a unit column or more.

Overpressure results from the inability of pore fluids to escape at a rate which allows equilibrium with a column of static water connected to the surface (Swarbrickand Gluyas, 2003). Overpressure is influenced by time and geology, being dynamic rather than static. Overpressure is in a non-equilibrium state, and the distribution and magnitude vary,being time dependent on geological age of surrounding sediments and interfering mechanism (Adebiyi and Akhigbe, 2015). Overpressures are retained in low permeability sediments such as shale, or in sediments that are bounded by low permeability lithology. It is generated through disequilibrium compaction. Pore pressure can be predicted in a basin where there are means of measuring porosity, wireline logs, sonic, density, resistivity, seismic velocities, and monitoring while drilling. Compaction is not entirely an irreversible process, but during unloading there is little rebound in porosity, but more in velocity.

Overpressure involves the interaction of several factors comprising sedimentation rate, thermal expansion of fluid, fluid source term, and gas generation within the sediment, which culminated in the generation of gas from the over pressured sediment, translating to rate of increase of overpressure with time. On the other hand, overpressure also involves the rate of dissipation of gas from the sediment with time, upon occurrence of seal failure: (outburst, piercing or drilling through, or blowout), fluid compressibility, and fluid flow. Furthermore, if the sealing system about the sediment column is not in-place overpressure will not be attained, no matter the magnitude of fluid generated. Overpressure magnitude however dissipates rapidly (geological timescale) once hydrocarbon generation ceases, (Carcione and Gangi, 2000). Significantly, overpressures in the Niger Delta environment (figure 1) follow the pattern of occurrence in low-permeability sediments, or in sediments bounded by low permeability lithologies. Thus, the overriding causes include 1. Reduction in pore volume by applied stress e.g. disequilibrium compaction, 2. Fluid volume change, e.g. hydrocarbon generation, and aquathermal expansion, 3. Fluid movement and buoyancy mechanisms, e.g. vertical fluid movement and hydrocarbon buoyancy. Compaction involves porosity loss, driven by effective stress. Porosity serves as a proxy to effective stress whereas, disequilibrium or under-compactioninvolves sediment supply coupled with low permeability, that inhibits dewatering at a rate quick enough to allow pressure equilibrium (hydrostatic), thus retards compaction.As long as there is subsurface pressure generation from the overcompacted sediment which exceeds the escape capacity, then there is bound to be an overpressure. The hydrostatic pressure which is a product of the unit weight (w) and vertical height (h) of fluid column, is affected by the concentration of dissolved solids including salts and gases in the fluid column and varying temperature gradients. The rate of gravitational compaction of sediments of a depositional basin is limited by the low permeability of the shale sediments and minor argillaceous sediment members. The degree of expulsion of water from pore space by compaction is reflected in the relationship between abnormal formation pressures, velocity of fluid expulsion, and pressure height through the sedimentary column (Ekweozor, 1991, Ekweozor and Daukoru, 1994).

The rapid rate of sediment-burial in the soft shales regime usually encountered at depth in many wells of thisPart of Eastern Niger Delta, gives the sediment less time to de-water leading to 1. More overpressure, 2. Overpressure starting shallower, 3. Higher porosity and permeability, 4. Reduced overburden (for same depth).

Due to losses encountered during the drilling of OKWUKWE-1which recorded increase in mud weight of 12.0ppg, and overpressure at the bottom with equivalents pore pressures of 10.7ppg, the well was terminated at 7980ft nearly 151ft before the planned TD. The well logged a continuous column of shale to the tune of 275ft thickness from 7600ft – 7975ft, with characteristics under compaction and overpressures of gas shows. The prospect was located at the northeastern portion of the Niger Delta with the target of encountering the sequence of Oligocene sands and shales, lying below the base of the fresh water sands of Benin Formation. But no oil shows but rather gas shows.

Withstructural faulting and sediment block-displacement at subsurface depths there has been provision for lateral stresses, giving rise to common areas of high overpressure in these areas of high lateral stresses. Compressional settings involving folds, thrusts, and the large columnal shale at depths which simulates the conditions of the diapiric behavior of Akatashales which tend to show forth in recognizable trends in this Eastern part of the Niger Delta especially Emeabiam and Ilomba fields. The Eastern part of the Niger Delta from Emeabiam, Owu field, Iheoma and Emebiam fields through Ilomba to Ohaji South 1 (Figure 1) hasunique geologic characteristics.The Iheoma-1 structure is an anticline, characterized by a sequence of Oligocene sands and shales, lying below the base of the fresh water sands.

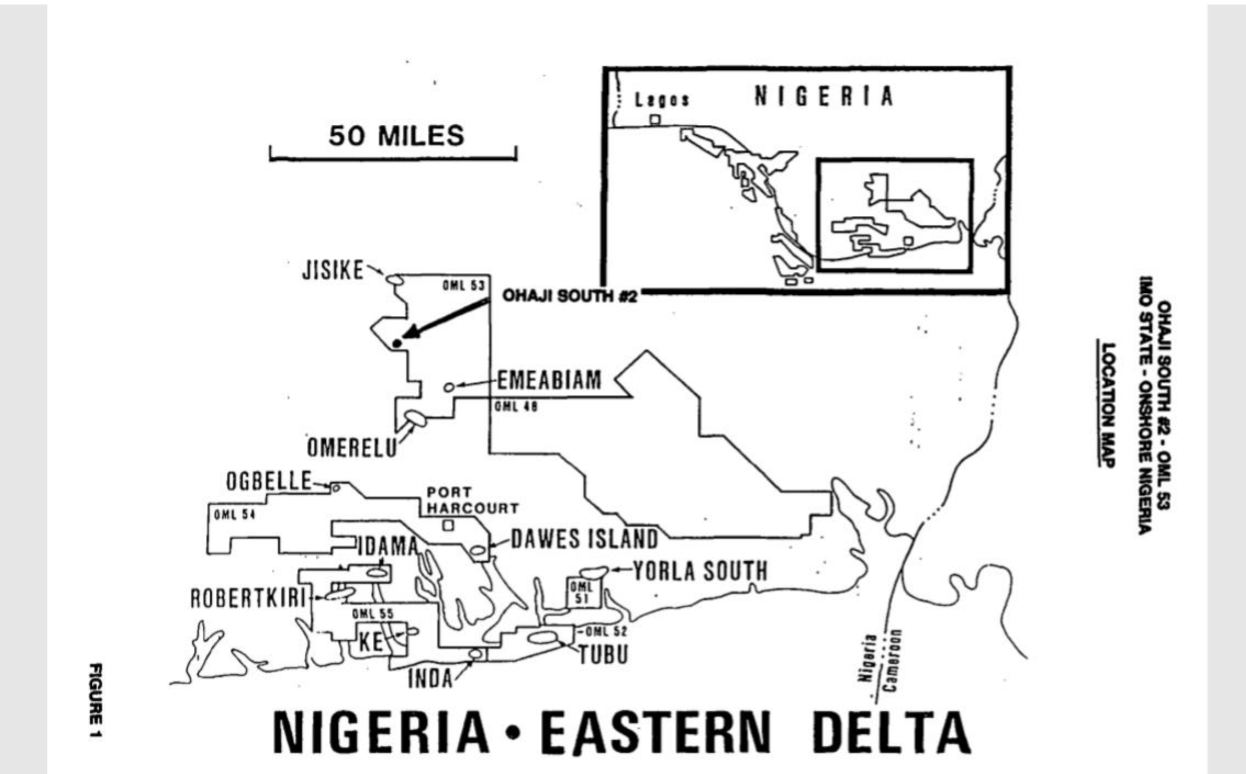

Figure 1: Overpressures in Emeabiam-Omerelu-Ilomba-Iheoma field location wells with unique signatures in Eastern Niger Delta

Over pressures occurred at depths in certain wells which were not always deep enough to suggest entry into the Akata Shales. This is the reason for over pressures above the Akata shale.

This is ascribed to under compaction of shalesediments of considerable thickness, 100ft and beyond. Most common causes: under compaction, hydrocarbon generation and expulsion (Barker1992) Shell Research Studies. Under compaction, overpressure, occurred when fluids could not escape from sediments during burial. Intra-subsiding deltaic settings, including parts of Niger Delta,low permeable shale and correlated Iheoma-1, Iheoma-2, Iheoma2ST, Iheoma-2ST2, which are located 3km WSW from Iheoma-1 well along the crest of the Iheoma structure which is a 4-way dip and updip fault closure against the downthrown side of the arcuate, east-west trending, southward dipping main structure building fault. The wells were drilled into estimated 2,315ft and 2358ft thick paralic sequence of interbedded Oligocene sands and shales lying below the base of fresh water sands respectively.

2. Geologic Setting

Three litho-stratigraphic subdivisions exist in the Niger Deltasubsurface geology. It comprisesthe Benin Formationsand, alternating sequences of sandstone and shale known as Agbada Formation and the underlying shale deposit known as Akata Formation. Benin, Agbada, and AkataFormations range in age from Tertiary to Recent, Paleocene to Eocene respectively. These are the three main formations have been recognized in the subsurface of the Niger Delta complex (Orife and Avbovbo 1982). The three formations were laid down under continental, transitional and marine environments respectively (Reijers, et al, 1997). The Benin Formation was deposited in a continental – fluviatile environment and mainly consists of sands, gravels, and black swamp deposits which vary in thickness from 0 to 7000ft. The Agbada Formation was laid down in paralic, brackish to marine fluviatile, coastal and fluvio-marine environments and consists of interbedded sands and shales. Many sub-environments have been recognized within these major units. The Agbada Formation becomes much shalier with depth and varies in thickness from 0 to 15,000ft. The Akata Formation consists of marine silts, clays, and shales with occasional turbidite sands, and silts, forming sinuous lenses. The Akata Formation varies in thickness from 0 to 20,000ft and like the other two formations, age varies from Paleocene to Recent. Deposits belonging to these three formations have thicknesses dependent on location. The Benin Formation and its equivalent form extensive outcrops inland from the Agbada Formation and south of the outcrops of the Ameki Formation and Imo Shale. The Akata Formation outcrops subsea on the delta slope and open continental shelf.

3. Objective

1) From the 40 oil wells in the Emeabiam-Omerelu-Apani-Ilomba-OhajiSouth-JisikePart of Eastern Niger Delta, identify characteristics of Overpressures at infected horizons or about reservoirs sands, over pressured zones at various depths of cumulative lithologic column of shales.
2) Identify evidence of Overpressure, Overbalance (psi)and comparison with Hydrostatic Pressure (psi) and Formation Pressure.
3) What are the unique indicators of Over pressured zones in this Part of Eastern Niger Delta?

4. Methodology

Reportsfrom original well histories of Emeabiam, Omerelu, Apani, Okwukwe and Iheoma-1, deciphering well pressure/overpressure trends while drilling progressed from one well to the other. 2) Well logs (Sonic logs, Mud logs, etc.) and Seismic velocity data were examined.

In order to calculate the pore pressure using sonic data the following formula is required:-

$$(S-(S-pfn) \times (dT\ normal/dT\ actual))\ /0.052$$

Where: S : Overburden Gradient (psi/ft)
pfn : Normal Pore Pressure (psi/ft)
dT : Sonic Transit Time (usec/ft)
0.052: Conversion coefficient from psi to ppg.

If the interval to be calculated was of uniform lithology, then a fixed formula could be used in the plot. However, we were dealing with at least two different lithologies, sand and shale, to change the formula whenever there was a change in lithology; which will not be practical in a log output. The velocity data used for calculating the overburden pressure was imported from the Sonic log. Of certain wells in the Easter Niger Delta, at the entry into thick column of shales was synonymous or suggestive of entry into the over pressured zones. Some locations revealed that after about 100ft of sand, and then followed by a zone of 300ft of shale of characteristic under compaction was tantamount to generation of overpressure,orabandonment.

5. Results and Discussion

5.0 The occurrence of abnormal gas generation in the shale columns of low permeability attributebecame associated with the occurrence of over-pressured zones, especially when bounded by low permeability media. Gas reading became an important gauge in under compacted shales and the formula C2/C3 ratio also relevant. Gas ratios are relevant in providing a pointer to abnormal pressures in the shalecolumns before transiting to soft shales of diapiric behavior, which can be ascribed to the AkataShale. Pore pressure studies in Alaoma-2 revealed a change from normal to abnormal at depths 6850ft with pressure gradient rise from 0.447psi/ft to 0.556psi/ft at 7540ft (Alaoma-2, TD).

In APANI-1 there occurred a large sedimentary deposit comprising Upper paralic sequence over 3000ft thick (depth 5200ft-8950ft) to Upper marine paralic sequence (8950ft-9717ft) being mainly shale to deeper horizons, Lower Paralic sequence (9717ft-10,272ft), and Lower Marine Paralic sequence comprised predominantly of shale. The Upper marine paralic brought about deposition of mostly transgressive shallow marine shales, which constitute the basal part of the Upper Marine Paralic sequence. Occurrence of Low carbonate deposition confirmed the reason for low traces of foraminiferain the associated Early Miocene to Oligocene-Sediments of Lower Marine Paralic.

5.1IHEOMA-2 recorded downhole dynamic seepage losses of drilling mud of 12 bbl/hrand total loss of circulations. The well seepage losses and the total loss of mud in hole were ascribed to highly porous sand section drilled with excessive mud overbalance.

Due to excessive well dynamic seepage losses while reaming down the hole after drilling to complete depth (TD) at 9,310ft mud loss of 300bbls was recorded. Highly viscous pills were pumped several times and the mud treated to control the losses. The pump flowrate was reduced to reestablish balance. During cases of pressure shortfalls, several light fall spots were encountered in this section from depth 5900ft – 9,310ft. The nature of popping shale formation drilled in this phase caused shale bridges, tight spots, and excessive cavings. These popping shale formations and excessive caving contributed greatly to the problems of tight spots and hole bridges.

At Umusage and Igbuku, near the West flank of the River Niger, symmetrically opposite the Eastern fields of Emeabiam and Ilomba, the overpressure rose to 3000psi, exceeding the overburden, the choke was opened allowing gas to blow out and the well was abandoned.Shale density measurements revealedconsistent increases with depth in this part of Eastern Niger Delta, (see Figures2 and 3),and changes from expected trends can indicate changes in pressure. Overpressures in the area was commonly signaled by gas shows, kicks, or undercompaction revealed as a kick out of the hole. Other times that kicks may occur out of the hole are during extensive logging, wireline or fishing operations. These operations may cause swab formation fluids into the well, resulting in a kick. The problem with kick detection while running casing is that the operation is not focused on kick detection or shutting in the well. But upon detection of a kick the well should be shut in using casing rams or the annular preventer (closing pressure may have to be modified). A crossover circulating swage should be made up prior to the casing run both for circulating and in case the casing float fails. With an influx in the hole, gas expansion causes additional volume to be displaced out of the hole (more than the pipe's displacement). The fluid displaced out of the hole and the pipe's displacement should always be carefully monitored and measured to be balanced. If they are not equal, there is a problem.Following gas/oil shows incirculation, the gas content increased in return fluidsand served as a good sign of abnormally pressured zone. Indicators from gas showswhen porous formations containing gas are drilled, cuttings containing gas are moved up the hole and the gas expands. As it returns to surface it may cause the fluid weight to be cut. If severe or shallow enough, gas-cut mud may cause a decrease in hydrostatic pressureConnection or Trip Gas or connection gas is the accumulation of gas that enters the hole during a connection or trip. Consistent Increases in these types of gases may indicate that the fluid to formation pressure differential is changing.Background Gas changes are regarded as a warning that pore pressure is also changing. Ceasing operations and circulating bottoms should clear most of the gas from the well. If gas levels remain elevated, an increase in fluid weight may be warranted. Compaction is largely but not entirely an irreversible process.

EMEBIAM-01
(GAMMARAY/RESISTIVITY/POROSITYLOG/SATURATION/LITHOL)

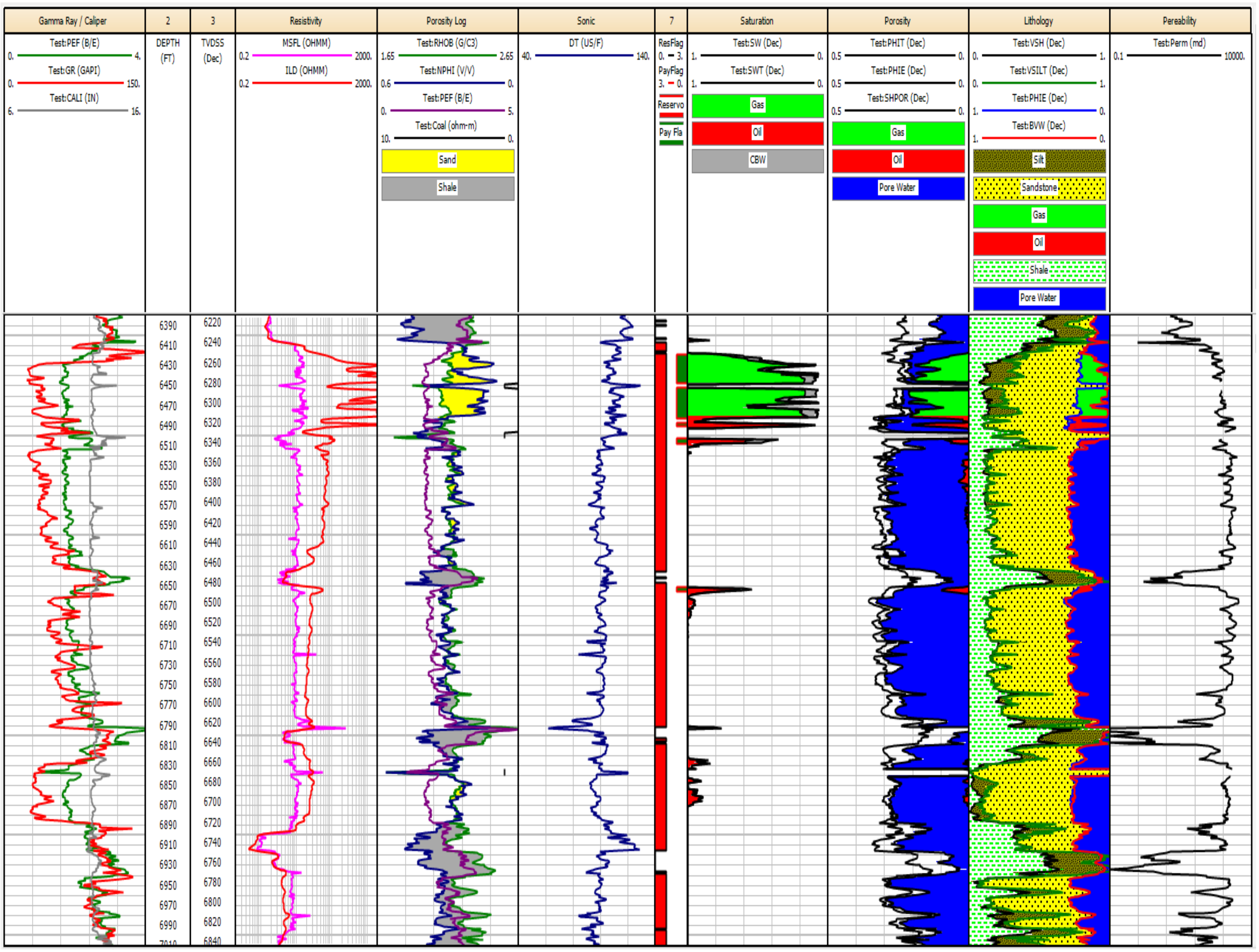

Figure 2: Thick pile of Shale Column before the TD and Pressure kick.

5.2 OKWUKWE-1 CASE STUDY

The original Okwukwe-1 well crossed the near surface sands and a minor fault into the thick column of shale sediments and penetrated 350ft of the shale that kicked out gas shows with increasing pressures, which caused abandonment of the well. Okwukwe-1 Redill was done to capture the deeper horizons but the problem of over-pressures prevented the completion of the objection. Due to losses encountered during the drilling of OKWUKWE-1 which recorded increase in mud weight of 12.0ppg, and overpressure at the bottom with equivalents pore pressures of 10.7ppg, the well was terminated at 7980ft nearly 151ft before the planned TD, Figure 2. The well logged a continuous column of shale from 7600ft – 7975ft, amounting to 275ft thickness with characteristic undercompaction and overpressures of gas shows. The prospect was located at the northeastern portion of the Niger Delta with the target of encountering the sequence of Oligocene sands and shales, lying below the base of the fresh water sands of Benin Formation. But no oil shows but rather gas shows.Another well OKWUKWE 1RD and EMEABIAM-01 weredrilled to test deep targets that not reached by the original Okwukwe-1 well, that abandoned because of overpressure. The evaluated 1100ft of Oligocene paralic section which was oil-bearing in Odinma-1, 4.5km to the west. This paralic section of interbedded sand and shale lies relatively updip at the proposed Okwukwe location and underlies a 1100ft thick section shale. The original Okwukwe-1 well apparently crossed a minor fault to penetrated 350ft thickness of shale before emergence of problems of over-pressures which culminated in abandonment of the well. There was no correlation below 7900ft of the original well.

5.3 Alaoma Case Study

Appropriate methods of Overpressure predictions to identify pore pressureevaluation based on the D'exponent corrected (dxc), shale density trends, flowline temperature, connection gas, data from offset well (Ohaji South-1x) among other overpressure detection parameters. The prediction commenced from 1924 ft (below the 20" casing shoe) to TD (13,625ft), mud weight equivalent ranging between 8.3ppg and 15.6ppg. The **gradual increase** in the **pore pressure** necessitated the **raise in mud weight** from 8.8ppg at spud to 10.5ppg at 8270ft. At 8650ft mud weight was raised from 12.0ppg to 12.2ppg in response to increasing pore pressure estimation. Pore pressure increased to an equivalent of 11.6ppg at 9100ft, with the mud weight subsequently raised to 12.9ppg. A uniform trend (continuing gradual increase) in pore pressure was observed from 9100ft to 9700ft, showing an average of about 0.2ppg per 100ft. The pore pressure at 9700ft remained 12.6ppg until 10200ft where it increased slightly to 12.7ppg.

From 10,400 – 10,900ft the pore pressure was estimated to range between 13.0ppg and 14.0ppg mud weight equivalent. No change on pore pressure was observed thereafter until 12,700ft when it increased to 14.2ppg.

The fourth maximum flooding surface at the total depth represents Oligocene -Miocene boundary. It is of a sedimentary sequence deposited in the outer shelf to coastal plain environment. This interval lies within the Benin and Agbada Formations, consisting of interbedded sand/sandstone and shale beds. The thickness of the shale beds increased with depth. Below the 7540ft depth the thickness of shale increased greatly and seemed to be only thick shale formation therefrom. Thus, the shale formation served as the source and cap rocks within the hydrocarbon bearing zones. The pore pressure through the wells appear to be hydrostatic until at greater depths where there is display of signatures of overpressured zones. Drilling into overpressured strata is hazardous as the fluids under such pressures are prone to rapidly escape, by way of "blowout."

5.4 Enhancing Environments

In fast subsiding deltaic environment such as the Niger Delta's, low permeable shale, and undercompaction relates directly with overpressures. If formation waters are not able to escape, the trapped water rather than the rock matrix carries or bears the overburden, resulting in undercompaction of shales. Controlling parameters include,

1) Sand/shale ratio which relates to the permeability structure of the sediments is significant in overpressures.
2) Edeki (1991) described the occurrence of low sand/shale ratio and high subsidence rates in the paralic successions, as main hazard especially in interdeltaicembayments is another relevant factor in overpressures.
3) There must be huge columns of shale capable of isolating sand bodies in order to activate the overpressured zone (Nwajide, 2013).
4) The cumulative overburden load on sediment is borne partly by the solid rock matrix and partly by the pore fluid (Terzaghi's principle: In Osipov, 2015).

The Vertical Effective Stress (VES), the difference between the overburden pressure (lithostatic) and the fluid pressure controls the compaction process of sedimentary rocks. Increase in fluid pressure will reduce the VES and affect compaction in terms of porosity and bulk density, (Onuoha, 1981; Opara and Onuoha, 2009).

5.5 Overpressure Trends, Characterization & Predictions

Drilling results have shown that very large Pressure differences can be maintained by faults of limited throw and/or thin shales. The rate of buildup of overpressures was largely determined by the rate of change increase of shaliness into large column of shale thickness. In exceptional cases, inflated pressures result in a stepwise increase in pressure gradient from 10kPa/m (0.44psi/ft, hydrostatic) to 18-23 kPa/m (1 psi/ft, lithostatic). In this part ofEastern Niger Delta, there was no change on pore pressure observed thereafter until 12,700ft, and from 13,500 – 13,800ft TD, the pore pressure increased gradually from 14.5ppg to 15.6ppg.Hole pressure regime was hydrostatic down to 7830ft depth. But pore pressure estimation showed overpressure conditions which led to corresponding increases in circulating mud weight.

Evidences reveal that formation pressures in flowing regimetend tohigh pressure conditions which at greater depths f(z), the flowing rate was at the minimum. The under compaction at greater depths, which activates overpressures, especially with the characteristic shalieror more shale with column of large thickness with depths.

A hazardous occurrence in over pressured zones was imminent and indicativefrom the Low Sand/Shale ratios, in the paralic successions, especially in interdeltaicembayments. There were huge columns of shale capable of isolating sand bodies in the overpressured zones.

The gas readings did not reflect optimum crude oil accumulation reservoirs but depictedmore of gas composition in highly over-pressured zones (Connan and Van de Weide, 1975).Gas ratios were relevant to point the direction to abnormal pressures of gas composition. Increase of gas components greater than methane (C1) when measured at the surface was also pointer to possible occurrence of abnormal pressures.

Table 1: Indices of Highly Overpressured (depths) zones: Gas Reading Suggestive Trends

Depth Int. feet	BGG	MAX	C1	C2	C3	Ic4	nC4	iC5	nC3
3050-4780	5	20	2500	……	….	…	….	…	…
4780-5150	30	50	30000	900	….	…	….	…	…
5150-5640	110	1050	200000	10000	400	90	110	60	
5640-6220	90	105	65000	1600	110	20	90	95	15
6220-6842	120	100	10500	300	100	50	75	30	15

The gas readings did not reveal optimum crude oil accumulation reservoirs, but more of depiction of gas abnormal increase proportionate composition symbolizing highly over-pressured zones (Table-1).

Gas ratios are relevant to providing a pointer to abnormal pressures of gas composition, or abnormal pressure detection. Increase of gas components greater than methane (C1) when measured at the surface is also pointer to occurrence of abnormal pressures.

Indices of Highly Over-pressured zones included gas-trends suggestive and a Huge Shale column is also a relevant attribute. In COMPACTED FORMATIONS, propane (C3) content tends to be lower than ethane (C2) content, such that the **C2/C3 ratio is greater than 1**.

On the other hand, in UNDERCOMPACTED FORMATIONS a reversal in relationship, such that **C2/C3 ratio falls below 1**.

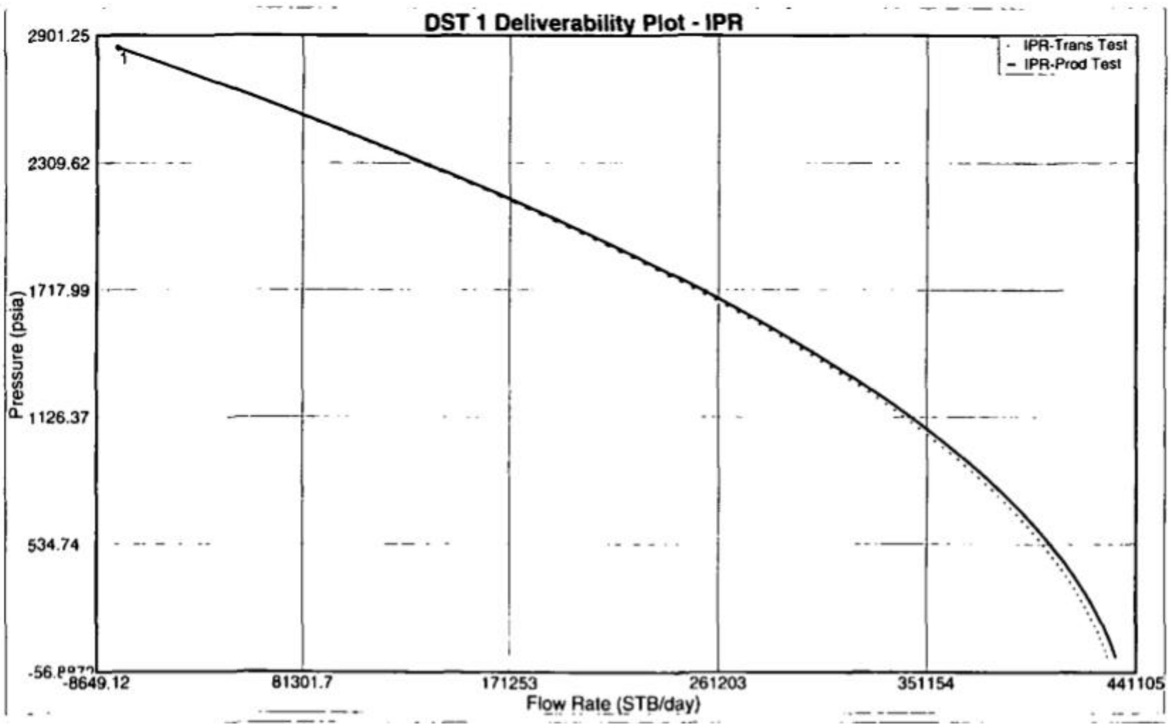

Figure 3: Trend of formation pressure in flowing characterization

The total reservoir flow function monitored for effective deliverability. There was occurrence of high pressure or over-presssuredshales encountered in the Owu-1offset well below 8300ft. Due to lack of seismic data in the area, it was difficult to predict where the pressured zones were encountered in Alaoma-1.

Section of almost wholy shale from 6179-6842ft TD: Total gas readings were reduced a little with increased mud weight. This section exhibited characteristics of overpressure, with splintery shale caving and pipe connection gases. Based on large increase in splintery shales in cuttings, gas readings, and increase in mud- temperature.

5.6 Deductive Attributes of the Overpressured Zones:

Temperature Trends and Thermal Conductivity:
Heat transfer occurs from the formation to the drilling fluid while circulating. There is heat loss during circulating mud transfer to the annulus. Temperature probes installed in the suction tank and the possum belly continuously monitored mud temperaturesduring drilling operation to detect abnormal pressures.

The measurement of flowline mud temperatures can provide advance-warning of abnormal pressures. The geothermal gradient is the rate of formation temperature increase with depth, expressed as (°C/100m). Average geothermal gradients vary from 1.8°C to 4.5°C/100m depending on the location. At some locations, the actual gradient varies from depth to depth, depending on the efficiency of various rocks and fluids to conduct heat towards the surface.

The temperature change between any two depths depends on the thermal conductivity of the rocks and fluids in the interval. A formation with relatively low thermal conductivity is an insulator. Below the insulating formation, heat will build up until the increased temperature results in greater heat flow across the insulator. The thermal conductivity of oil, gas, and water is lower than that of a rock. An abnormal pressure formation contains more of fluids, than a normally pressured formation at the same depth (Figures 3, 4, and 5). The thermal conductivity in an overpressured formation is lower than in a normally pressured formation. The temperature gradient measured across an overpressured interval should be higher than the gradient for an equivalent normally pressured interval.

There is a high risk associated with unexpected overpressures. Knowledge of the pore pressure using seismic data, for instance from seismic-while-drilling techniques, The significance is that the data is required for planning in real time to control potentially dangerous abnormal pressures. The importance of detecting potential overpressured zones does exist. Thus, seismic velocities which suggest anomalies arising from under-compaction or resulting from “not-having enough-time” to dewater and undergo effective compaction or consolidation of sediments to yield optimum velocities with depth.

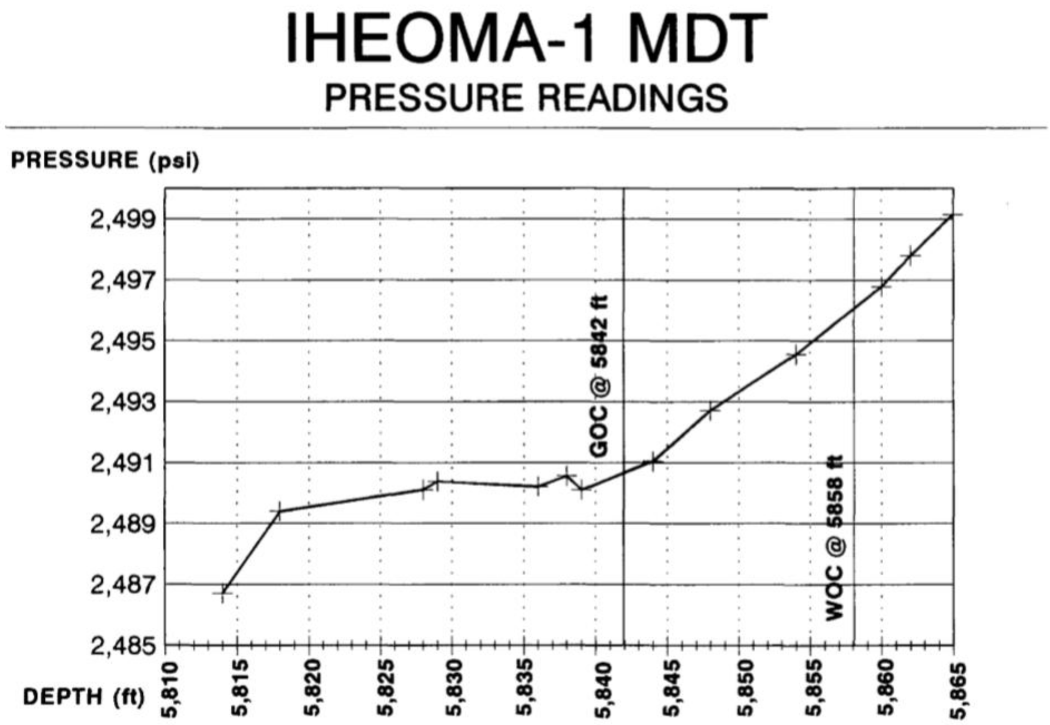

Figure 5: Illustration of Pressure increase with Depth in IHEOMA-1

In this part of Eastern Niger Delta, entry into the thick column of shales was suggestive of entry into the overpressured zones. Sometimes in the sequence, after about 100ft to 150ft of sand, and followed by300ft of shale, of characteristic undercompaction was tantamount to generation of overpressure. The depositional pattern was such that played out as hydrostatic pressure, up till about 14000ft where the shale thickness grew as much as about 12.5ppg (almost equivalent to 6500 psi).

The Iheoma-1 well though a wildcat was targeted to TD of 7547ft. The prospect was located in the East-central portion of OML-53, which lies along the NE margin of the Niger Delta. The well was first of seven exploratory wells in the field, and a 4-way dip closed and updip fault closed anticline, lying on the downthrown side of an arcuate, E-W trending, southward dipping structure building fault.

5.7 Magnitude of Gas-Ratios- Suggestive of Overpressured Zone

The gas ratio is relevant to indicate the presence of hydrocarbon, possible abnormal pressures of gas composition, and abnormal pressure detection. Increase of gas components greater than methane (C1) when measured at the surface is also a pointer to possible occurrence of abnormal pressures. In compacted formations, propane (C3) content tends to be lower than ethane (C2) content such that the C2/C3 ratio is greater than one. On the other hand, undercompacted formations show a reversal in relationship such that C2/C3 ratios falls below one.

Gas measurement in the in-situ condition is normally different from measurement at the surface due to preferential degassing of the lighter components(Mitchell and Grauls, 1998), and Stone (1999).

This occurrence was identified in Iheoma, two sections were suspected as overpressured, from 6170ft-6450ft and from 6550ft-TD, where the C2/C3 ratio in each was slightly below one.

These aretools for predicting the approach to overpressured zone while drilling (Figure 6).

The presence of pipe connection gas and shale cavings are also confirmatory tools for the prediction of overpressured zone. Typical example occurred as of a pure shale zone representing the overpressured zone which is characterized by large increase in the amount of splintery shales in cuttings, significant increase in mud-temperature, and gas backgroundand a C2/C3 ratio very close to 1, coupled with pipe connection gases.

Overpressure is a drilling hazard that is the cause of several blowout consequences. Such can be predicted by Geophysical or seismic methods. Subsurface overpressured compartment can beprognosed within a plus or minus depth error bar and that becomes a tool to raise a red flag and then to assure primary well control best-practiced plans are used throughout. Each red flag compartment identified must have two essential elements: a pressure Sourceand a structural containment Trap**.** The most common pressure source is from rapid sedimentation or mass transport deposition as hazardous anomaly from seismic interpretation and correlation. Other causes of over pressure are related to sand collapse, gas charging, and/or salt tectonics**.**
Within the overpressured formation, the rock is weak because its effective stress is low. Drilling rates of penetration, therefore, increase relative to the overlying rocks. However, the mud weight needs to be carefully monitored so that it is high enough to hold back the pore fluids, but low enough not to fracture the rock. Poisson's ratio decreases with increasing pore pressure. This decrease can be predicted ahead of drilling from computed seismic attributes.

Overpressured zones may be shallow or deep. Shallow geopressure zones typically consist of gas-charged sand bodies that derive their charge from underlying gas pools which has leaked upward through a series of fractures or faults. Deep overpressure zones occur in thick shale layers that have been buried so rapidly that escape of their contained water was arrested. Geophysical techniques have proven useful in predicting abnormally pressured zone.

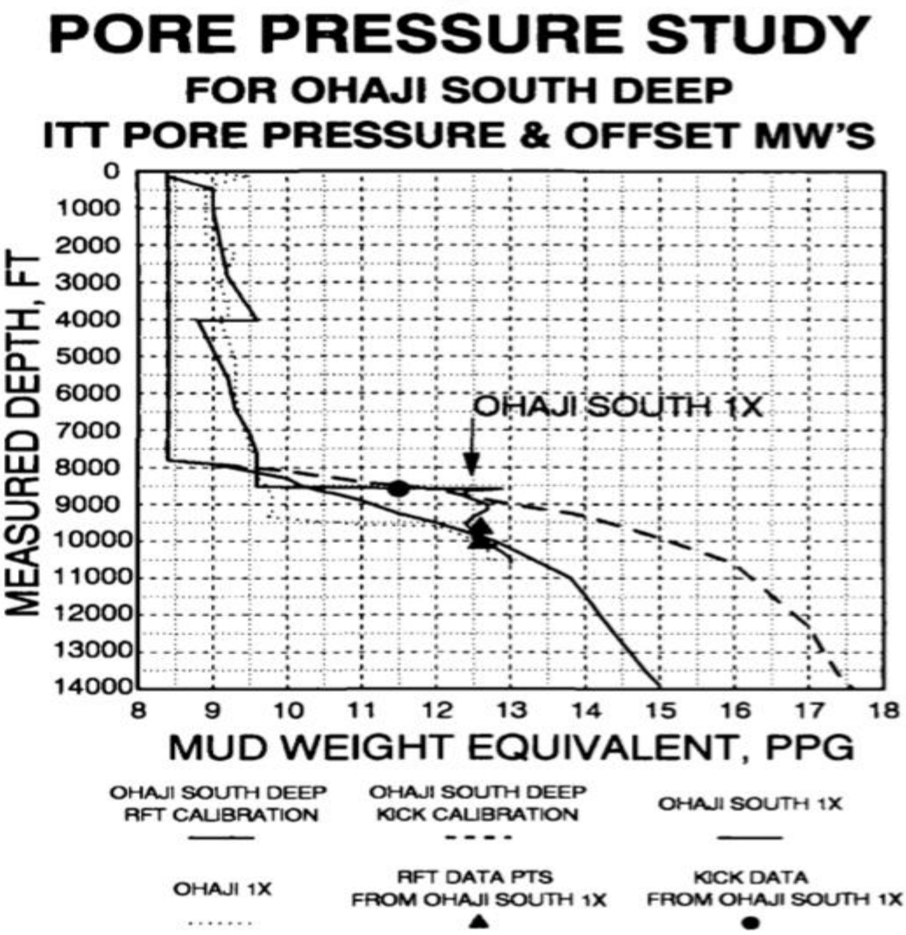

Figure 6: Pore Pressure at Measured Depths and Appropriate Mud Weight Equivalents

6. Conclusion

In this part of the Eastern Niger Delta, penetrationinto thick columns of shale in certain oil and gaswells portrayed entry into the over-pressured zones. Abnormally pressured formations contain more of the fluids than the normally pressured formations at the same depth.Recognizable trends in this Eastern part of Niger Delta were shown in Okwukwe-1 well where overpressure with excessive pore pressure controlled kick-outcome. The presence of wells of continuous columns of shales such as 275ft thickness (7600ft-7975ft), characterized zones of undercompacted and overpressured sediments. The uniqueness of the over-pressured zones in this axial trend of Eastern Niger delta, encountered 1,100 ft of Oligocene paralic section. Underlain is a thick shale of 1100 ft and contiguous shale deposition of 350 ft thickness revealing associated minor fault, an occurrence before abnormal increase in pressure that resulted in well abandonement.

Thispart of the Eastern Niger Delta is characterized bylarge sediment-loading of marine transgressive deposits of large thickness of shale columns and sometimes with argillaceous interbeddings where the depth of such shale columnsapproaches therangeofabout 6750ft to 10,000ft, overlaid by sand bands of considerably lesser thickness. The overpressures associated with these columns of shales result from inability of pore fluids to escape at the rate that allows hydrostatic equilibrium. Certain of these large thicknesses of shale columns were associated with under compaction and high pore pressure, resulting in overpressure-generating zonesof gas kicks.

There are signs of kicks,which precedes thepenetration of flagged overpressure zonesas formation pressuresappeared higher than the mud hydrostatic pressures acting on the rock face of the well. When this occurred, the greater formation pressure hadthe tendency to force formation fluids into the wellbore, which in turn translates towards the surface.

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