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Porosity as an overpressure zone indicator in an X-field of The Niger Delta Basin, Nigeria

NFOR, Bruno Ndicho and OKOLIE Michael Ikechukwu

Anambra State University, Uli P.M.B 02 Uli, Nigeria

ABSTRACT

Over the past decades, overpressure zones have been routinely identified in the Niger Delta by means of resistivity logs, dc component logs, direct measurements (using pressure level detectors attached to BHA) and penetration rate of the drilling bit. The present research, however, applies porosity as an alternative method for overpressure zone detection. The application of porosity as a tool for overpressure detection is demonstrated using plots of porosity versus depth for two wells in an X-field in the Niger Delta. Results show that between 5000ft and 7000ft depth, (for well-1) there is continuous decrease of porosity values with depth. At 7000ft, however, there is an abrupt shift to the right side of the plot, indicating abnormally high porosities (at least for the delta), with values ranging from 25% to 35%. Such abnormally high porosities suggest that the pore fluids support a disproportionately large part of the overburden (from the Benin Formation mainly), leading to an overpressure scenario. Geologically, overpressure zones indicate restricted vertical and horizontal permeability, (possibly by a high density of growth faults common within the Agbada Formation), high shale-to-sand ratios, deposition of impermeable sediments and montmorillonite diagenesis among other factors. In deed, results from the computation of sand-to-shale values indicate a marked change of ratios from the previously 2:1 to 3:5 in the formations, underscoring the association of overpressure zones with thick undercompacted shales. Montmorillonite diagenesis here is confirmed by high GR values of between 74 - 94 API. When compared with the resistivity-depth plots for same wells, the identified overpressure zone lies at the same interval, thus lending credence to the authenticity of porosity-depth plots as reliable indicators for overpressure zone in the Niger Delta.

Key words: Overpressure zone, porosity, under compaction, Niger Delta.

INTRODUCTION

Several methods have been applied in the determination of formation pressures in the Niger delta, including rate of penetration (Jorden and Orval, 1964), temperature and pressure (Paul H.

Jones 1978) changes. The mechanisms, structure and level pressure development in a rock-fluid system vary significantly and the variation is dependent on the basin history, geological structure, the thickness and rock composition of the sedimentary section and activity of the geodynamic processes. In drilling operations, it is necessary to determine formation pressure of various formations penetrated by the borehole. This enables the driller take extra precautions while penetrating abnormally high pressure zones in order to avoid damages, including fatalities due to blow outs. Such abnormal pressures are called geopressure and the formations where they occur are known as overpressure zones.

The identification of the tops of overpressure zones in any formation penetrated by a borehole enhances the use of normal drilling techniques of the borehole. This also reduces the cost of drilling the entire well as the special drilling technique will be applied only in the overpressure zones. The inability to accurately predict and control overpressure zones have led to both loss of lives and of wells in the past, which could have been avoided if the tops of those overpressures zones had been detected prior to penetrating them. The present research applies porosity as an alternative method for predicting overpressure zones. The advantages and disadvantages of using other methods in the petroleum industry in the Niger Delta to predict overpressure are also compared herewith.

A Brief Geology of the Niger Delta

The Niger Delta basin of Nigeria, is located in the southern part of Nigeria, and is bounded approximately by Longitudes 5^{0}00'E - 8^{0}00'E and Latitudes 4^{0}00'N – 7^{0}00'N, covering an area of about 75,000 sq km with a sedimentary thickness of between 30,000 to 40,000ft.This Tertiary basin has been extensively discussed by workers such as, Burke, 1972; Merki, 1972; Murat, 1972; Short and Stauble, 1967 and Weber, 1971. etc. It consists of three main lithostratigraphic sedimentary units; a Recent to Pleistocene aquiferous Benin Formation, underlain by a Miocene to Pliocene deltaic marine to paralic petroliferous sand/shale Agbada Formation and a basal low density, high pressure marine shales belonging to the Oligocene/Miocene Akata Formation. The target of oil exploration/exploitations within the basin is the Agbada Formation, which contains the best reservoirs. The presence of a combination of rollover structures, faulted anticlines, growth faults and some thick shale columns, though favourable structural traps for petroleum accumulation, are sometimes sites for overpressure zones, especially if very close to the naturally overpressure underlying Akata shales.

Causes of Geopressure

Overpressures in the world's sedimentary basins are known to be associated with permeability barriers, tectonics, shale diagenesis, basin structure and under compaction among other factors. (Hillier,1991). Research also shows that undercompaction is the major cause of geopressure in the Niger delta (Ogbobe, 1997). Undercompaction results from disequilibrium in the rate of sedimentation and fluid expulsion. Compaction is a digenetic process that begins with burial and may continue over a long span of time. This process increases the bulk density of a rock and reduces its porosity. In Niger Delta, undercompaction is commonly experienced within the Agbada and top of the Akata Formations.

Overpressure Indicators

Parameters routinely used in the detection of overpressure zones during oil and gas operations in the Niger Delta include the use of temperature, dc component, rate of drilling bit penetration among others. These parameters are achieved only if other drilling parameters are kept constant. The temperature plots may not be reliable due to inability to keep continuous measurement along depths. Other factors that affect temperature measurement include lithologic changes. This research work thus proposes the use of porosity as a reliable parameter for overpressure detection in Niger Delta. It is noteworthy to mention that this method is not new; it has been applied in several other basins worldwide (Hinch, 1980 and Bonham, 1980).

MATERIALS AND METHODS

The materials used for this work include; GR logs, porosity data and excel software. The porosity values were plotted against depth on an excel spread sheet. Then, deviation trends were used to identify the **tops** of the geopressure zones.

RESULTS AND DISCUSSION

The results of the porosity plot of well-1 in an X-field in the Niger Delta basin show that initially high porosity values ranging between 25% and 35%, (between 3000-5000ft) interpreted to be within the Benin Formation begin to decrease at a depth of 5000ft. The decrease continues steadily to a depth of about 7000ft. However, after 7000ft depth, there is an abrupt shift of porosity values to the right. This point is considered to be the top of a geopressure zone. This high porosity value remains almost constant till a depth of 11,000ft., indicative of an overpressure zone. Figure1 shows the variations in porosity values upon which these deductions are made.

Results of well-2 show a steady and expected decrease in porosity from a depth of 3400ft – 4400ft. However between depths of 4000ft and 4500ft, there is a slight increase in porosity followed by a steady decrease in porosity as the Agbada Formation is penetrated. This sharp increase is tricky and could be easily misinterpreted as a top of an overpressure zone at 4000ft. a common knowledge, however, of the geology of Niger Delta indicates that this depth still lies within the Benin Formation, a zone not usually associated with overpressure. Thus, these abnormally high porosity values are associated with highly aquiferous gravelly fluvial deposits, (as validated by the GR log –fig. 4), which shows that the interval consists of coarse sand to gravelly lithology. This scenario is specifically interesting because, it emphasizes the fact that not all abnormally high porosity zones should be interpreted as overpressure zones. Abnormally high porosities are associated with overpressure zones if the anomaly occurs in thick undercompacted shales, as is common in most parts of the Agbada Formation.

Under normal circumstances of sedimentation within a basin, there should exist a steady decline in the porosity of sediments/sedimentary rocks in response to overburden weight increase. In the present study, the high but steadily decreasing porosity values (37% - 35%, between 4000-5000ft) observed in well-1 are in consonance with overburden weight increase within the aquiferous Benin Formation. This is confirmed by the high sand-to-shale ratio of approximately 2:1, as interpreted from the GR log (see fig. 2) of the well-1 at this interval.

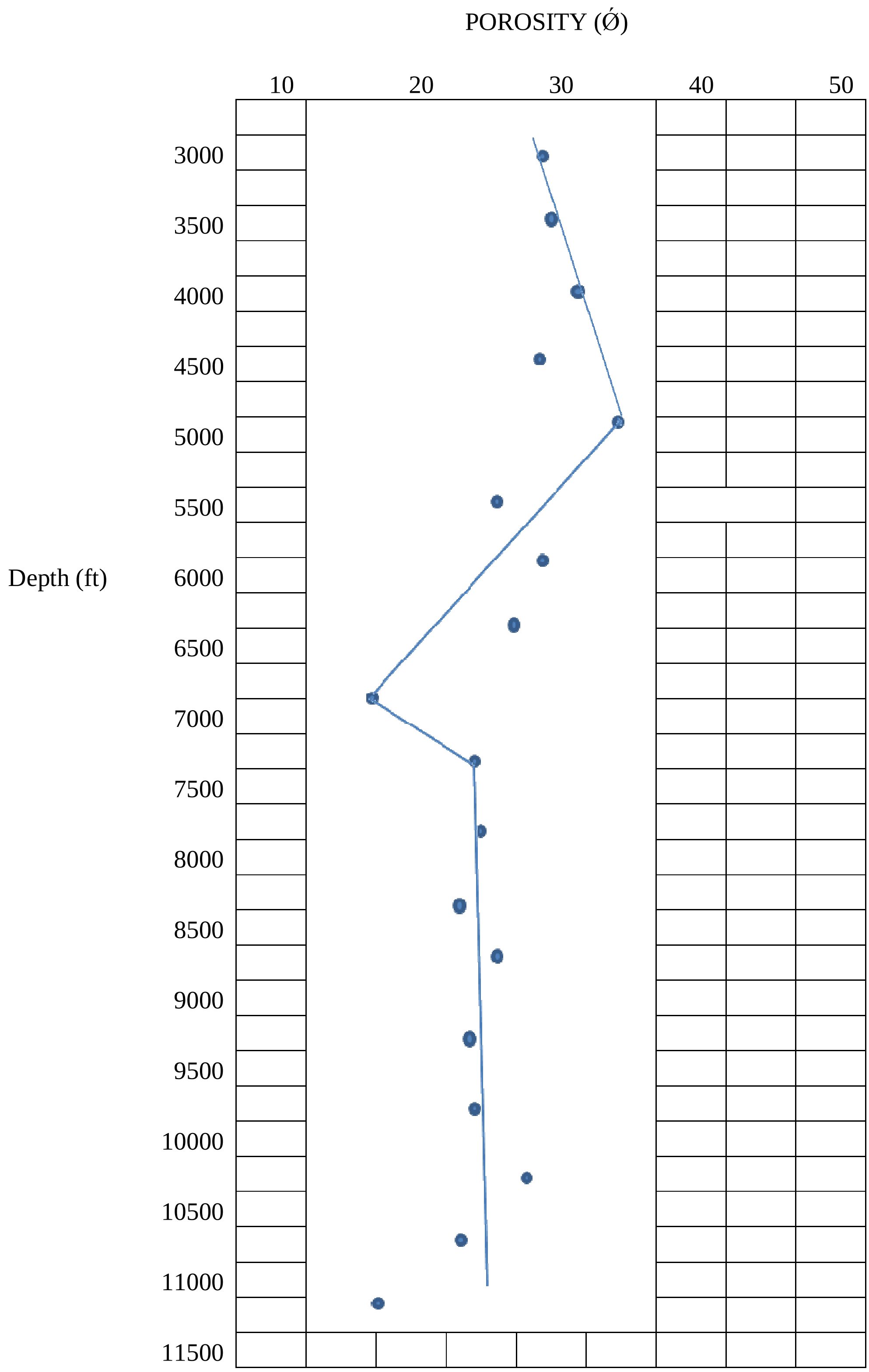

Fig. 1 Porosity Deviation Trends of Well-1

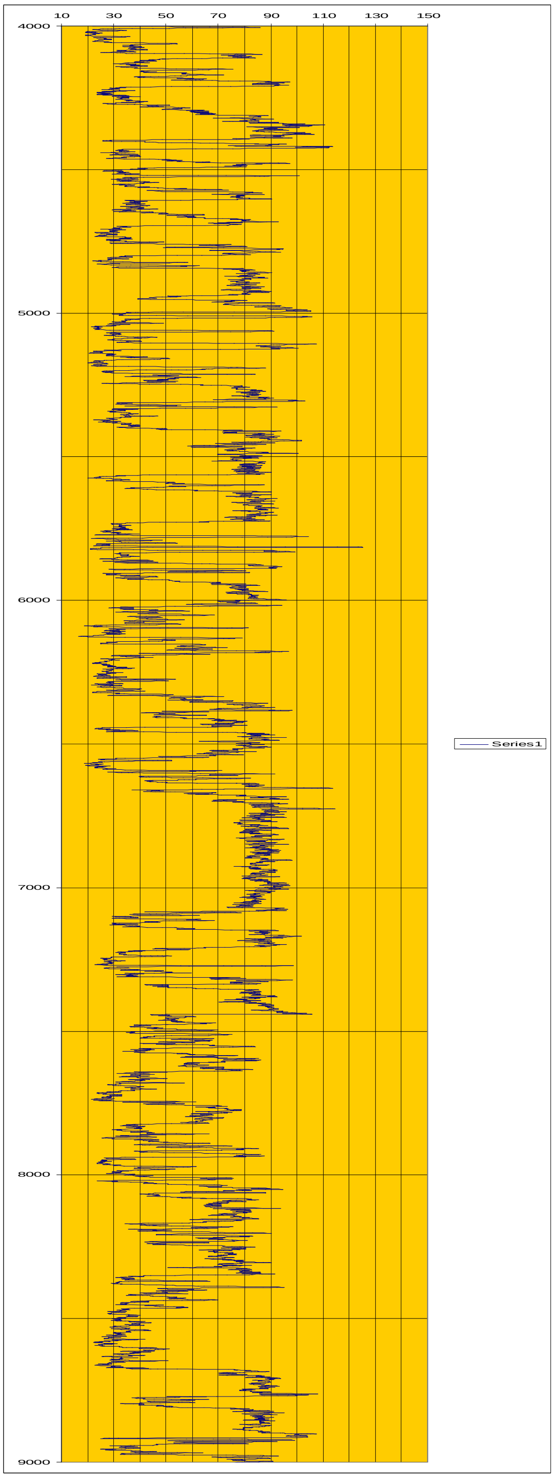

Fig. 2. Gamma Ray (GR) log of interval of Interest for well-1

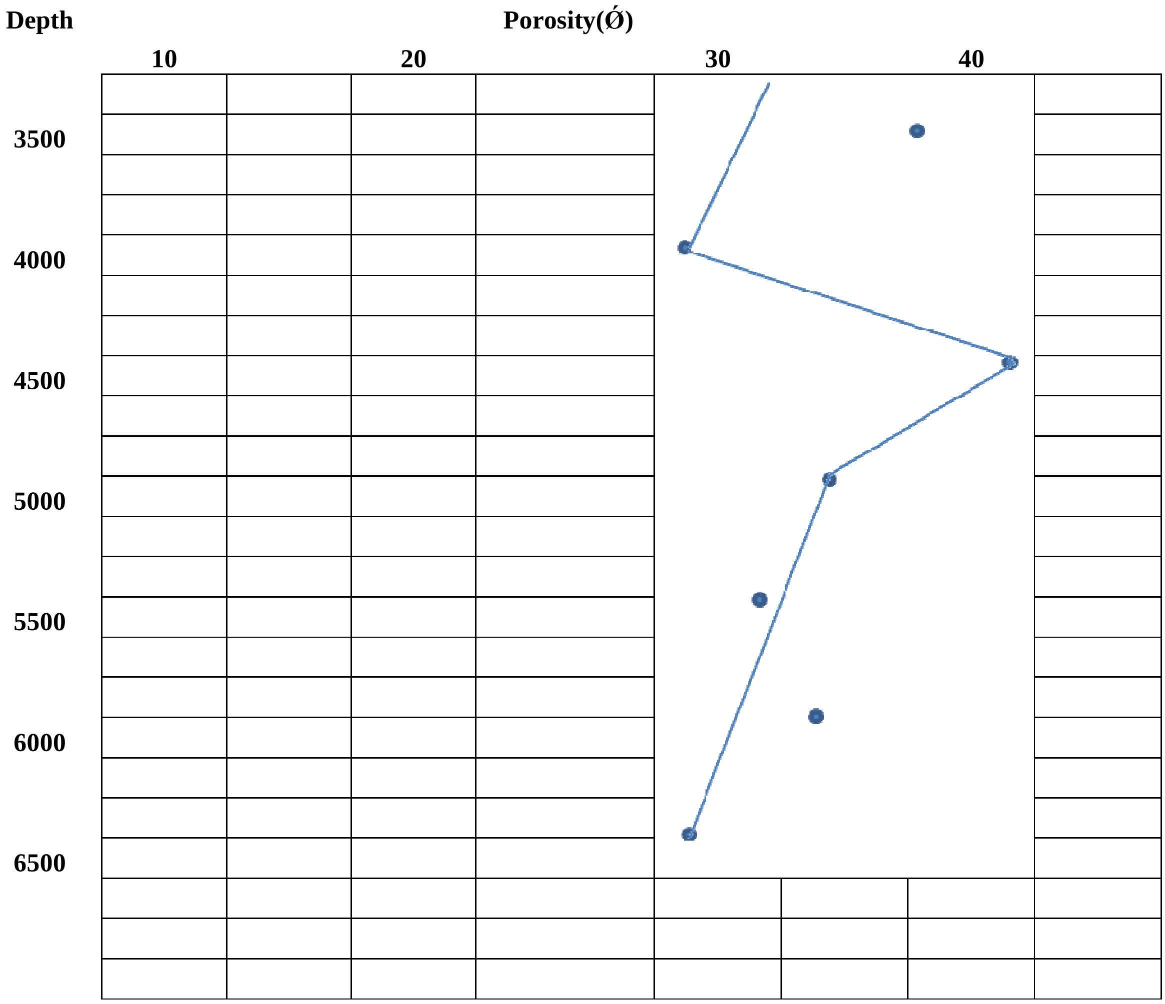

Fig 3. Porosity Deviation of Well-2

The decrease in porosity values between the depths of 5400 – 7000 (from 37 – 15%, before a dramatic increase to 27% between 7,000 and 7,500ft, a value which remains virtually constant down to 11,000ft), is characteristic of the of an overpressure zone, whose top is at 7,500ft. (fig.1.). The overpressure zone thus occurs between depths of 7000ft – 8800ft., a zone suspected to be in the Agbada Formation. The increase in shale-to-sand ratio (see fig. 2. – the GR log at the corresponding interval) confirms the presence of the Agbada Formation.

In well-2, porosity values decrease sharply from 37% - 27% between 3300ft and 4000ft. This is followed by a sharp increase from a depth of 4000ft to 4500ft. from whence a steady decrease in porosity values are then noted down to about 6500ft depth. The high sand-to-shale values (see corresponding GR log – fig. 4) at the interval of 3300ft -4000ft., is indicative of a highly porous Benin Formation. This is in contrast to the low sand-shale ratios, typical of the Akata Formation, (when compared with the Benin Formation), exhibited from 4500ft downwards. There is thus an evidence of sharp porosity increase without any corresponding pressure increase for the reasons already given.

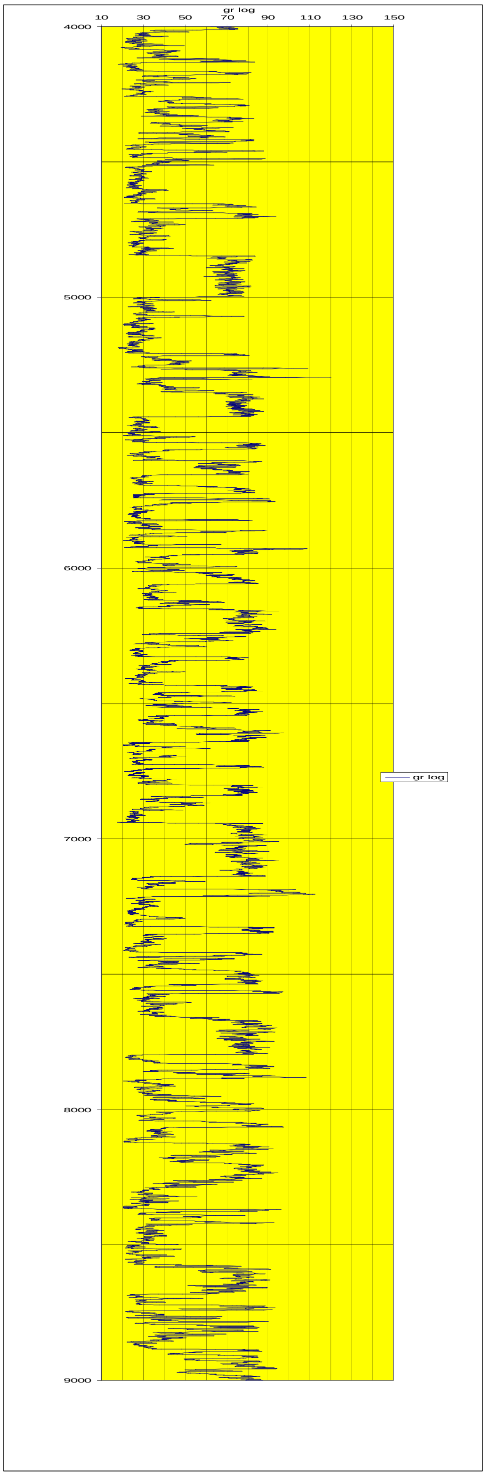

Fig. 4. Gamma Ray (GR) log of interval of Interest for well-2

The overpressure zone identified thus far herewith is shown to occur within thick shales. Such an overpressure zone is possibly associated with the presence of excessive pore fluids (in thick shales) whose escape during normal compaction process have been restricted by growth faults, rapid sedimentation and partly by shale diagenesis, which are all common features in the Agbada Formation. If enough precautions (e.g. slow penetration, increase in drilling mud density etc.) are not taken prior to the penetration (if it is really necessary to do so) of these zones, a blow out could occur.

CONCLUSION

The present research work has presented porosity as an alternative indicator for overpressure zones in the Niger Delta basin. This method is more precise and can be easily applied. It is even more economical than other methods. Porosity is a major criterion in determining a good reservoir hence lending credence to its usefulness as an overpressure indicator. It is thus strongly recommended that, porosity be used as an alternative for overpressure indicator in the Niger Delta basin. Correlated porosity plots taken over wide field acreage is thus recommended as a departure point for such a valuable exercise.

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