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Porosity and Permeabilty Anisotrophy in Parts of The Niger Delta Using Core Data.

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Abstract:
Porosity and permeability anisotropy distribution in parts of the Niger Delta was addressed in this study using core data. The core data was analyzed in laboratory to determine porosity, horizontal and vertical permeability from which permeability anisotropy was computed and cross plots were used to represent them graphically. Results from this study shows the porosity level of this formation and distribution along the well-column which suggests two stacked reservoirs at 3920 – 3930m and 3940 – 3970m. Horizontal permeability and Vertical permeability were observed to decrease with increase in depth. Permeability anisotropy decreases with depth, ranging between 5.33 and 5.8 x 10^{-4}mD. The results of this work will reduce uncertainty in the exploration and evaluation of transmissivity of hydrocarbon from the reservoir.

Keywords: *Porosity, Permeability, Reservoir, Anisotropy, Horizontal, Vertical.*

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I. Introduction

Understanding the permeability of reservoir formation is essential because of its role in providing information about reservoir hydrocarbon recovery and the possibility of exploration. Whether a well has enough resources to be harnessed, completed and brought on line depends on the permeable nature of the reservoir. However, because different factors are responsible for the variations in the permeability of reservoir formations, it is often a difficult property to determine.

Reservoir description can be divided in parts to aid better understanding such as layers and grid blocks which explains the complex variations in hydraulic properties (porosities, permeability, capillary pressure and relative permeability), reservoir heterogeneity, geometry (morphology and continuity), and fluid content to evaluate, predict and establish formation lithology, porosity, hydrocarbon saturation, permeability, production and estimates the economic viability of a well (Archie, 1950). Rock permeability is dependent on the porous nature of a formation; porous reservoir is always permeable. Permeability anisotropy may be related to the depositional processes in the formation of reservoir rocks or the presence of grain scale which has a preference in its orientation. The analysis of permeability and its anisotropy helps in its features and factors that control them.

Johnson and Greenkorn (1960), Aigedion (2007), Farell et al., (1997), Uguru et al., (2005), Saddique et al. (1998) have all examined different models for permeability, permeability anisotropy and the use of coring and core ample to reduce uncertainties in reservoir evaluation. With the huge deposits of hydrocarbon in the Niger Delta, there is need to measure and estimate rock properties to evaluate hydrocarbon bearing formations for embedded resources accurately to aid its development and optimal utilization. This study aims to determine permeability anisotropy and evaluate reservoir fluid flow parameters in the area.

Location and Geology of Study Area

The study area is located in South Western Niger Delta. The Niger Delta is located in the Gulf of Guinea in equatorial West Africa. It lies between latitude 4^0 N and 6^0 N and longitude 3^0 E and 9^0E (Klett et al, 1997). It is a very prolific deltaic hydrocarbon province (Reijers, 1996) and a major geological feature of significant petroleum exploration and production in Nigeria (Whiteman,1982)

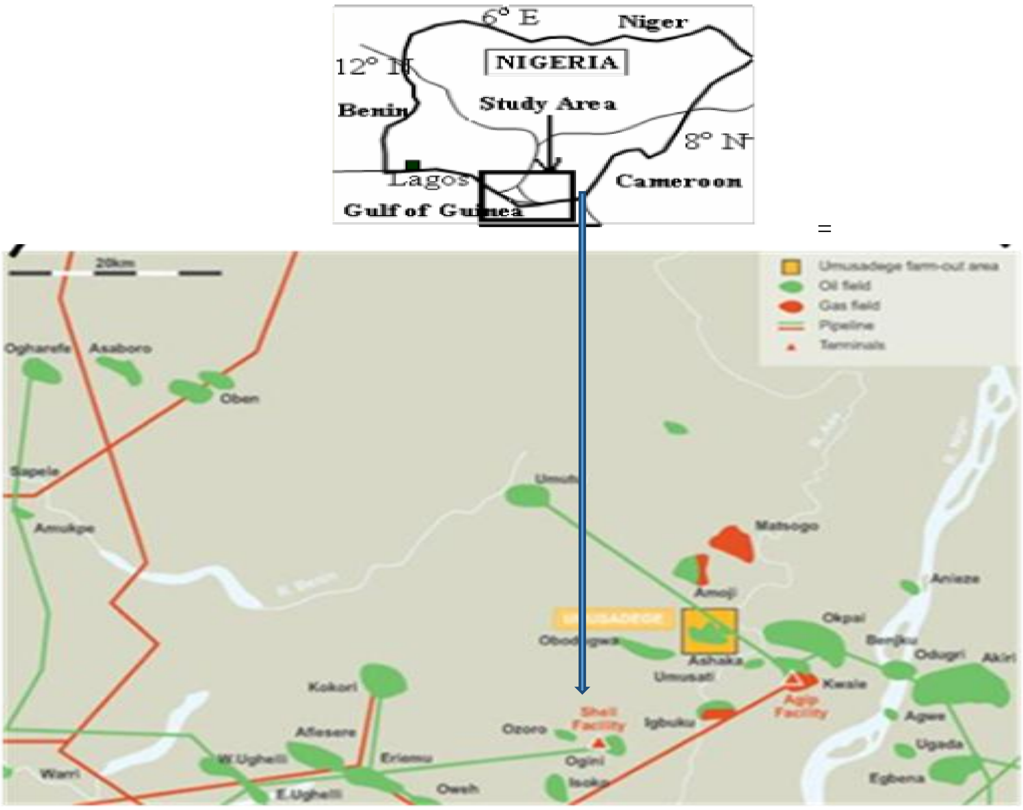

Fig 1: Map of the Niger Delta Showing the Study Area

The geology of the study area has been documented extensively by various researchers. According to Doust and Omatsola, 1998, The Niger Delta started to evolve in the tertiary times when classic rivers input increased. Eventually the Delta prograded over the subsiding continental oceanic lithospheric transition zone, and during the Oligocene, spread onto oceanic crust of the Gulf of Guinea Sediments were supplied from the weathering flanks of out-cropping continental basement through the Benue-Niger drainage system (Burke et al., 1971). It covers an area of over 70,000km^2 and is composed of a regressive clastic sequence reaching a total stratigraphic thickness of 30,000-40,000ft and is one of the world's largest delta.

Generally, the Niger Delta is made up of three stratigraphic units, these are: Akata Formation, which ranges in age from Paleocene to Eocene and has a thickness of about 6500m (Whiteman, 1982). It is the oldest stratigraphic unit in the subsurface of the Niger Delta. The top of the Akata formation is the economic basement for oil (Doust and Omatsola, 1989). Next is the Agbada formation which is transitory between the upper Benin formation and the underlying Akata formation. It is Eocene to Oligocene in age and consists of parallic siliciclastic that are more than 3500m thick (Corredor *et al*., 2005). It has micro fauna at the top while the base is characterized by a body of sandstone. The coarseness of the grains and poor sorting inn this formation indicates its affluviatile origin. This formation serves as the main hydrocarbon reservoir due to hydrocarbon accumulation confined within it (Ejedawe, 1981). The third unit is the Benin formation, the youngest unit in the Niger Delta. It is continental and consists of coastal plain sands, gravel with a few clay intercalations, consisting of late Eocene to recent deposits of alluvial and upper coastal plain deposits that are up to about 2000m thick (Avborbo, 1978). It is a continental deposit of probable upper deltaic depositional environment (Reijers *et al* 1996). It is Oligocene of age in the North on the subsurface and becomes younger progressively southward. Very little hydrocarbon accumulation has been associated with this formation. However, it is a water bearing formation and is the main source of portable water in the Niger Delta.

T**heoretical background**

Porosity is defined as the ratio of the pore volume to the bulk volume of a material (Abhijit, 2006); that is, the fraction of a rock that is occupied by pores and can be measured in the absence of flow using various techniques. In hydrocarbon reservoirs, the pore volume is available for the accumulation and storage of oil, gas and water. Porosity is normally expressed as a percentage of bulk volume as follows:

$$\phi = \frac{V_b - V_s}{V_b} = \frac{V_p}{V_b}$$

Where:

ϕ = porosity, fraction
V_p = pore volume
V_b = bulk volume of rock cm^3
V_S = solid volume, cm^3

Permeability is a measure of the ability of a porous material to transmit fluid (Wannel and Morrison, 1990). It is the ease with which fluids flow through any substance (Schlumberger, 1989). Permeability in a reservoir rock is associated with its capacity to transport fluids through a system of interconnected pores, where there are no interconnected pores, the rock would be impermeable. The standard unit of measurement for permeability is the Darcy (D) named after the French scientist who discovered the phenomenon.

One Darcy is defined as that permeability that will allow a fluid of one centipoises viscosity to flow at a rate of one cubic centimetre per second through a cross sectional area of one square cent per centimetre (Muskat and Botset, 1931).

the Millidarcy (MD) is more commonly used in core analysis and is one thousandth of a Darcy. That is 1/1000.

Permeability is express as:

$$Q = \frac{K . \Delta P . A}{\mu . L}$$

where Q = Rate of flow (cm^3/sec); K = Permeability (Darcy); ΔP = Pressure difference (atm); A = Area (cm^2); μ = Fluid viscosity (centipoise); L = Length (cm).

Permeability Anisotropy

Permeability that is homogenous and isotropic world reveals its value when the flow through a sample rock is measured (Ayan, *et al* 1994). However, due to rock type and grain size not been the same throughout a reservoir, it may lead to variations in permeability. Measuring permeability in different directions may yield different values because permeability measured at the same point in the horizontal direction may different from permeability measured in the vertical direction. The directional variation in the measurement of permeability is known as permeability anisotropy. According to Ayan *et al* (1994), anisotropy is the directional dependency on any type of measurement.

Anisotropic permeability is quantified by the ratio:

$$\frac{K_v}{K_h}$$

Permeability anisotropy is important in understanding fluid migration and fluid flow characteristics. Direction of fluid flow through a reservoir can be altered by anisotropy. This will adversely affect the fluid estimate and production behaviour.

II. Materials and Methods

Core sample measurements data used consists of vertical permeability, horizontal permeability, porosity, oil saturation and water saturation. These were used to analyse porosity, horizontal and vertical permeability from the well to aid in the interpretation of permeability values and estimates from the core data. Permeability anisotropy data was gotten from the ratio kv/kh ratio and it was quantified using cross plots establishing correlation between vertical and horizontal permeability in the reservoir.

Results and Discussion

The plots of porosity data against depth are shown in Fig. 2

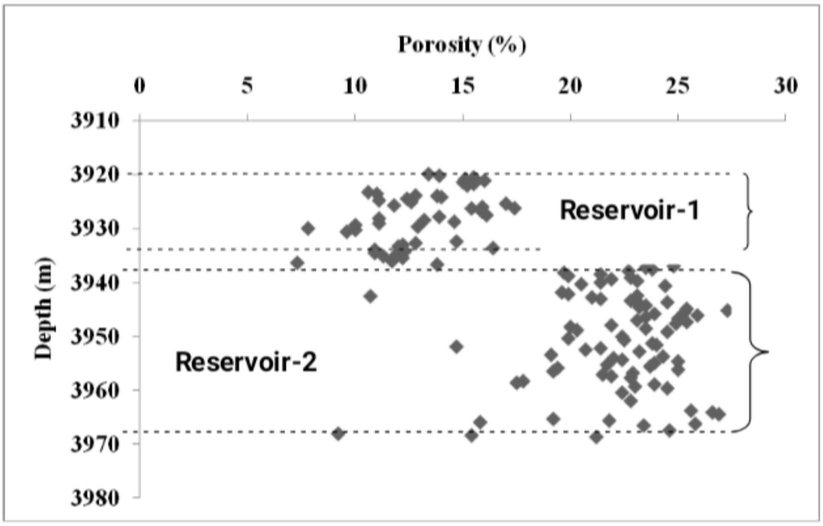

Fig 2: Porosity- Depth Profile

A cross plot of porosity against depth from the data distribution suggests two stacked reservoirs at 3920 - 3930m and 3940 - 3970m separated by an interval of 10m. It also displays decrease in porosity with increase in burial depth and due to compaction from overlying pressure.

The Well shows anisotropy in fluid flow directions. Depth- Permeability anisotropy profile Fig 3 indicates that permeability anisotropy decreases with depth ranging between 5.33 and 5.8 x 10^{-4}mD, this is due to reduced porosity with depth. The anisotropy displayed in the well is caused by heterogeneity in the reservoir rock and the presence of shale lithology.

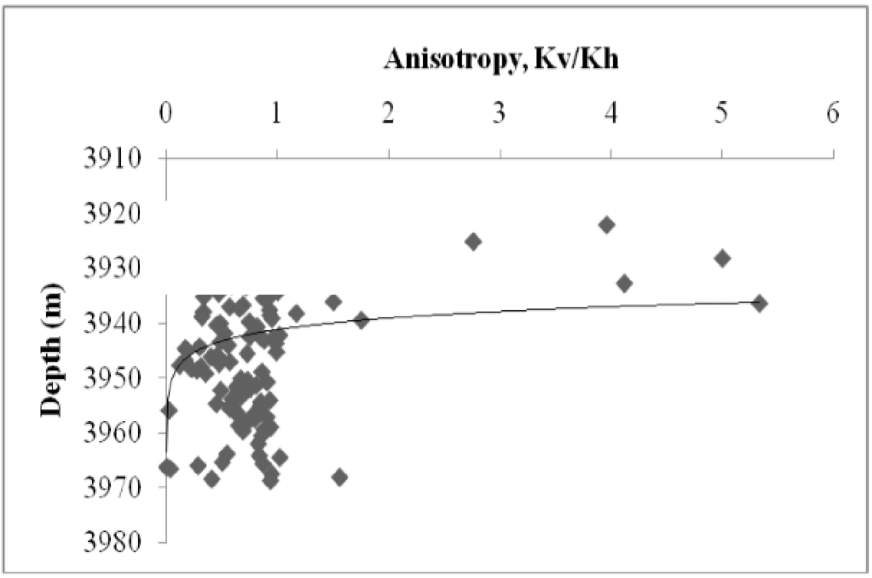

Fig 3: Permeability Anisotropy (K_v/K_h)-Depth Profile

III. Conclusions

This study was to estimate the porosity permeability anisotropy using core data from well located in the Niger Delta and graphical representation using cross plots. Profiles for depth – porosity, vertical - horizontal permeability and permeability anisotropy profiles yielded results which has shown that core analysis data is an essential method that can be used to estimate the permeability anisotropy of a reservoir.

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