IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 4 Ver. II (Jul - Aug. 2015), PP 31-38
www.iosrjournals.org

Porosity Estimation Using Wire-Line Log to Depth in Niger Delta, Nigeria

Akankpo Akaninyene Okon[1,] Umoren Emmanuel Bassey[2,]
Agbasi Okechukwu Ebuka[3,]
[1,2,3,] *University of Uyo, Uyo*

Abstract: *Porosity modeling was carried out in oil-wells of stacked reservoirs in south-east Niger Delta using gamma ray, resistivity, and sonic logs to determine lithologies and porosities. Lithologies of the formation were identified as sand and shale. Porosity values range from 0.013% to 94.08%. Porosity decreases with depth in normal compacted formation for the two wells .The following porosity equation has been modeled for the study area,* $Z = -3E\text{-}05\O_z + 0.5785$. *This implies that, in the absence of core samples, porosity,* φ_z *can be estimated at any depth, Z in the area of study. The results of the porosity modeling can be applied in petroleum evaluation and overpressure prediction. It may also be useful for sedimentary basin analysis of the region.*
Keywords: *Porosity Modeling, , Lithology, Reservoir, Sedimentary Basin.*

I. Introduction

The porosity of a sedimentary layer is an important parameter for evaluating the potential volume of hydrocarbons it may contain. In other words, one of the essential attributes of any hydrocarbon reservoir is porosity. Almost all reservoirs have porosity in a range of 5 to 45% with the majority falling between 10 and 20% (Selley and Morrill, 1983; Egehetal.,2001). Hubbert and Rubey (1959), Schmidt (1973), Selly (1982), Uko (1996) applied porosity analysis in the geodynamic processes, which influenced the evolution of sedimentary basins including the Niger Delta basin and continental margin of Nigeria, and hydrocarbon potentials of the basin. When porosity is combined with permeability, a region's hydrodynamics, hydrocarbon migration and accumulation in reservoirs could be evaluated. Porosity field could as well be used to predict abnormal pressure areas during oil-well drilling (Uko et al. 2013, Udo, et al 2015). Middleton (1984) used the surface porosity to carry out geohistory analysis of a sedimentary basin. Characterization of hydraulic properties of rocks, such as the porosity, is essential for dynamic basin analysis because porosity and permeability control the flow of subsurface fluids (Bachu and Undersschultz, 1992). Regional studies in basin analysis are necessary for understanding basin evolution and the generation, migration, and accumulation of hydrocarbons (Hitchon et al., 1987). Also, dynamic analysis deals with the structure and rocks in sedimentary basins and the dynamic processes taking place, such as the flow of formation fluids and the transfer of terrestrial heat from the crust to the surface. Bjorkun and Nadeau (1998) asserted that porosity and permeability distributions control fluid migration on timescales of tens of millions of years.

Chukwueke et al.,(1992) estimated surface porosity using only geophysical logs and obtained values for sand stone and shale as 43.38 and 70.09% respectively in the distil parts of the Niger Delta. Okiongbo (1998) worked in the north-eastern Niger Delta and observed subsurface porosity range between 10 and 25%, while Ofeke (1998) computed porosity values using porosity logs and obtained the subsurface porosity for central Niger Delta as 52% and 14%. Ikeagwuani (1979) obtained porosities of 35% and 15% at depths of 5000ft and 14000ft respectively. These workers used only porosity logs without core sample measurements to infer the porosities.

In this work, we modeled porosity equation for the study area in South-East Niger Delta from which porosity can be estimated at any depth for many applications.

Geology of the Niger Delta

Niger Delta basin is bounded by the geographical grids of latitudes $6^o40'$E and longitudes $8^o30'$N. It contains mainly Cenozoic formations deposited in high energy constructive deltaic-environments as differentiated into continental Benin, paralic Agbada, and pro-delta marine Akata facies (Doust and Omatsola, 1990, Short and Stauble, 1967).

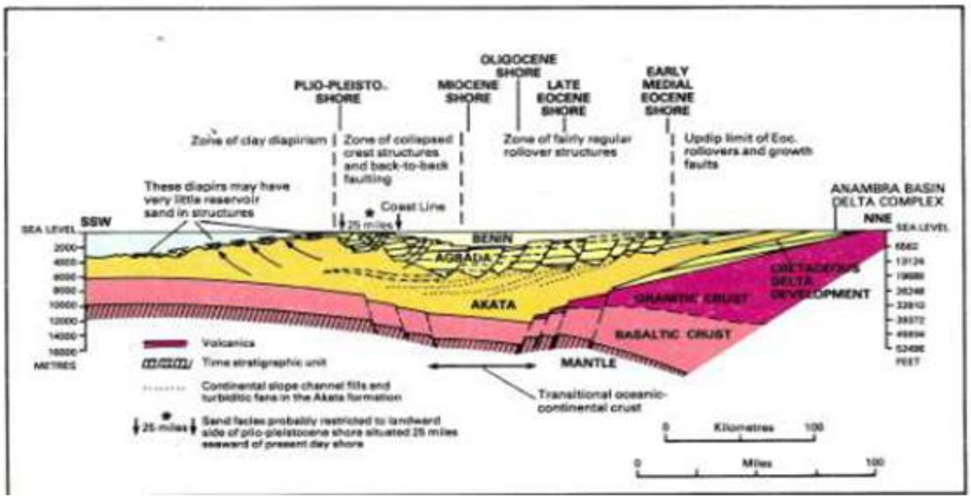

Figure 1: Structural section of the Niger Delta Complex showing Benin, Agbada and Akata formations (Short and Stauble, 1967; Weber and Daukuru, 1973; Whiteman, 1982)

The Benin Formation (Figure1) is the upper alluvial coastal plain depositional environment of the Niger Delta Complex. It extends from the west Niger Delta across the entire Niger Delta area to the south beyond the present coast line. The formation was deposited in a continental fluviatile environment and composed almost entirely of non-marine sandstone. It consists of coarse-grained sandstones, gravel lignite streaks and wood fragments with minor intercalation of shale. Benin Formation is of Miocene to younger age and has a variable thickness that exceeds 1820m.It is of Oligocene age in the north and is progressively younger southwards, ranging from Miocene to Recent. Very little hydrocarbon accumulation has been associated with this formation (Short and Stauble, 1967). The Agbada Formation underlies the Benin Formation. It was laid down in paralic brackish to marine fluviatile, coastal environments. It is made up of alternating sand stone, silt and shale. The sand stones are poorly sorted rounded to sub-rounded and slightly consolidated. The sand stones grade into shale in the lower part of the Benin formation. Agbada Formation ranges in age from Eocene in the north to Pliocene in the south. The sandy parts of the formation are known to constitute the main hydrocarbon reservoirs of the delta oil field sand the shales constitute seals to the reservoirs. The thickness of the formation reaches a maximum of about 4500m (Short and Stauble, 1967). The Akata Formation is the lowest unit of the Niger Delta complex. It is composed of mainly shale with sand stones and silt stones locally interbedded. The Formation becomes shalier with depth. It was deposited in a marine environment and has a thickness of approximately 7000 min the central part of the delta. The Akata Formation out crops off shore in diapirs along the continental slope, and on shore in the northeast, where they are called Imo Shale. The age of the Akata Formation ranges from Eocene to Recent (Short and Stauble, 1967).

Factors Influencing Porosity

Many authors have enumerated the parameters influencing primary porosity in rocks: age of the sediment (Boswell, 1961 and Maxwell, 1960, 1964; Scherer, 1987); mineralogy (Griffiths, 1964; Nagtegaal, 1978; Scherer,1987); maximum depth of burial (McCulloh, 1967 and Selley, 1978; Scherer, 1987); sorting (Beard and Weyl, 1973; Scherer, 1987); grain size (Beard and Weyl, 1973; Powers, 1953); grain sphericity (Tickell and Hiatt, 1938; Rittenhouse, 1943); grain rounding (Fraser, 1935 and Powers, 1953); grain orientation (Emery and Griffiths, 1953; Martini, 1972); formation temperature (Maxwell, 1960; de Boeretal., 1977); abnormal pore pressure (Von Engelhardt, 1960; Atwater and Miller, 1965; Selley, 1978); hydrocarbon saturation (Fuchtbauer, 1967; Selley, 1978); chemistry of formation water (Rentonet al., 1969; Wolf and Chilinggarian, 1976; Curtis, 1978; Giles and Maxwell, 1986 and Surdam et al.,1984).

Beard and Weyl (1973) investigated the influence of texture on the porosity of unconsolidated sand under wet conditions and concluded that porosity is little affected by changes in grain size for a given degree of sorting. He observed that a decrease in porosity takes place from 42% for extremely well sorted sand to 28% for very poorly sorted sand. Graton and Fraser (1935) found that the tightest packing of spheres is rhombohedral (26% porosity), and the loosest packings cubic (48% porosity). As these extreme cases rarely occur in nature (Beard and Weyl, 1973), Kahn (1956) and Dullien (1979) observed that most packings involve random assemblies but will also contain a size distribution of particles that are likely to be non spherical. He noted that the relationship between packing and porosity is not easy to isolate from other textural parameters, and is thus difficult to measure.

Important parameters influencing primary porosity are compaction (grain arrangement, plastic deformation, pressure solution, fracturing), authigenesis of minerals (cementation, also operating at near-surface conditions), and leaching (Wolf and Chillingarian, 1976; Kharaka and Berry,1976; Schmidtetal.,1977; Scherer,1987). Cementation and leaching are interrelated with many other parameters, such as pore-water chemistry, temperature, and hydrocarbon saturation.

II. Materials And Methods

Well Logs Pre-Processing

Volume of shale computation

Comparative examination of the gamma ray and density logs showed that the gamma ray adequately separates sands from shale. In some logs, there was no effect of radioactive sands on the gamma ray, while in others; effects of radioactive sand on the gamma ray were observed. The shale fraction of the reservoir in the five wells was estimated as shown in Table 1.

Table 1: VSH for the five wells

Well	Depth (ft) Low	VSH	Depth (ft) Top	VSH
1	5999	0.98905	4301	0.00099
2	7999	0.88532	6000	0.00171
3	10000	0.38370	8000	0.00608
4	11999	0.56835	10007	0.00096
5	13138	0.36149	12000	0.00042

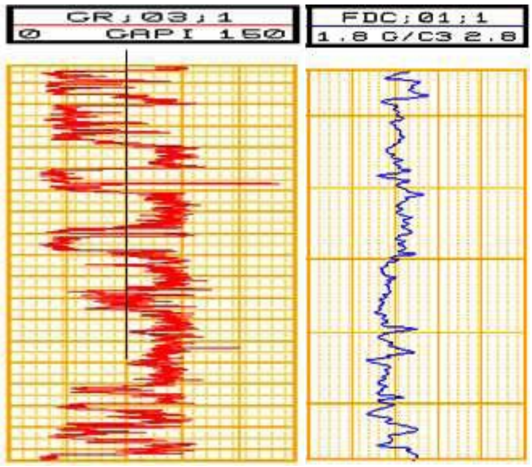

Figure 2: Density and GR Logs utilized

Porosity Calculation from Gamma Log

Although neutron porosities were available for the analysis, it was uncertain whether each logging was used to calibrate the same fluid and rock type. No information was available on the overall calibration technique. It is generally accepted among geoscientists that porosity calculation from bulk density logs is more accurate (Calderon and Castagna, 2007; Issler, 1992; Horsfallet al.,2013; Udo, et al 2015).

A log that measures interval transit time (Δt) of a compressional sound wave travelling through the formation along the axis of the borehole. The acoustic pulse from transmitters detected at two ormore receivers. The time of the first detection of the transmitted pulse at each receiver is processed to produce Δt. The Δt is the transit time of the wave front over one foot of formation and is the reciprocal of the velocity. Interval transit time is both dependent on lithology and porosity. Units: µsec/ft, µsec/m. Symbol :φ

The sonic tool is selected to calculate the porosity in a good borehole condition. The Sonic log is used for porosity determination according to equation 1.

$$\phi = \frac{V_p}{V_b} = \frac{V_b - V_s}{V_b} \qquad (1)$$

Where ϕ = fractional porosity

V_p = Pore Volume

V_b = Bulk Volume

V_s = Gain Volume

For a Gamma Ray value below our threshold 63.5 GAPI, the lithology is interpreted to be sand stone.

In the five wells, the average Porosity values ranges from 0.02% to 95.60%. The results of this study shows that clean sand reservoirs have better porosity than shaly sand reservoirs. In the clean sand reservoirs, the thickness of the reservoir is directly related to the porosity. For those reservoirs, higher porosity values were obtained for higher sand column sand vice versa. This study also shows that zones of coarsely packed sand stones in a reservoir have better porosity than zones of finely packed sandstones in the same reservoir.

III. Results And Discussion

Porosity was calculated for hydrocarbon and water-bearing reservoirs using the Gamma log. The plots of porosity data against depth are shown in Figures 3, 4, 5, 6, 7 and 8.These plots show normal porosity decrease with depth. In the Niger Delta, shale lithology increases with depth, while sand stone decreases. Our observation confirms the results of Friedman and Sanders (1978), Blatt et al., (1980) and Selly (1982) that porosity is lost with increasing depth of burial. It follows that porosity varies with lithology and depth, that is it decreases with increase in shale volume. The decrease of porosity with depth can also be thought of as variation of porosity with pressure. Within a specific depth and lithology, porosity is influenced by confining pressure as pointed out by Telford et al., (1976).

Fuchtbauer (1967) has pointed out that the presence of hydrocarbons also preserves porosity. In this study we observed that reservoir thickness is directly related to porosity. The thicker the reservoir, the higher the porosity.

The equation for the porosity trend for two wells is:

$$Z = -3E\text{-}05\text{Ø}_z + 0.5785. \qquad (2)$$

This implies that, in the absence of core sample or any porosity, φ_z, can be estimated at any depth, Z, in area of study.

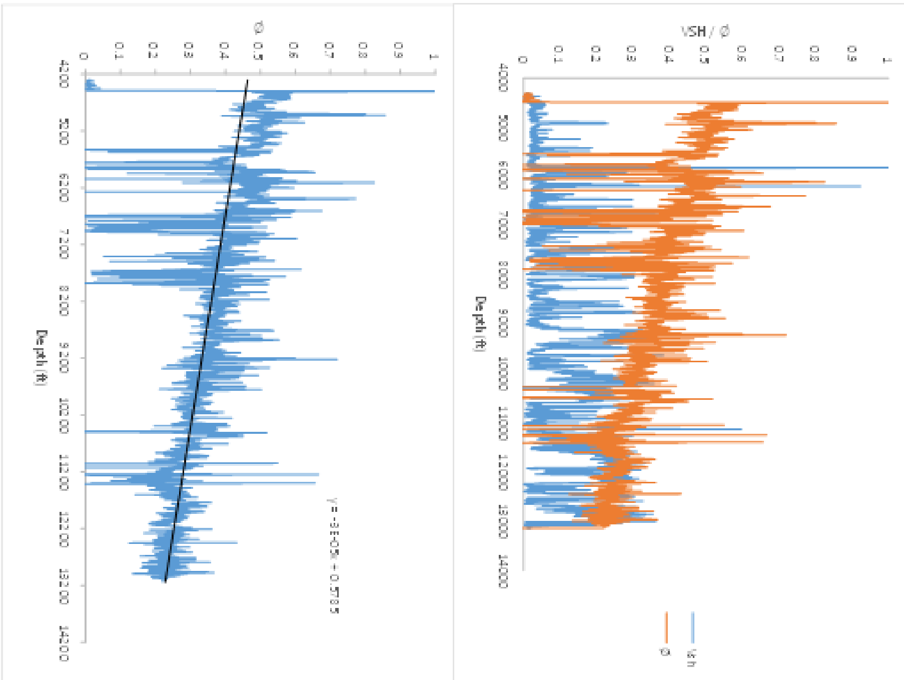

Figure 3: Complete Porosity against Depth and VSH / Porosity against Depth for the Well

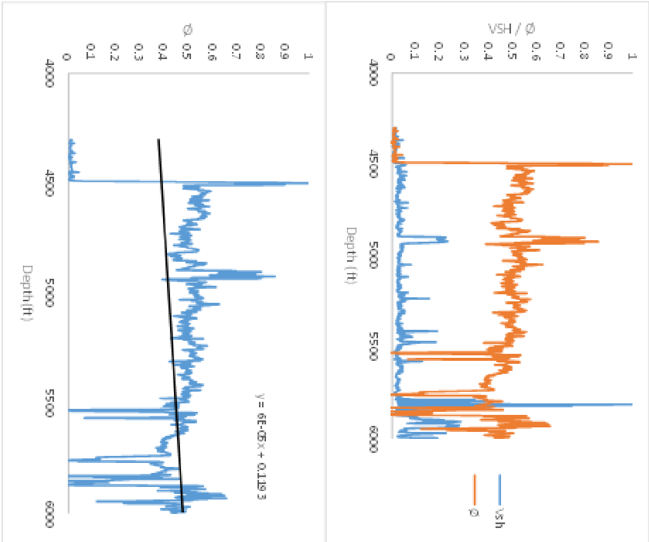

Figure 4: Porosity against Depth and VSH / Porosity against Depth for Well 1

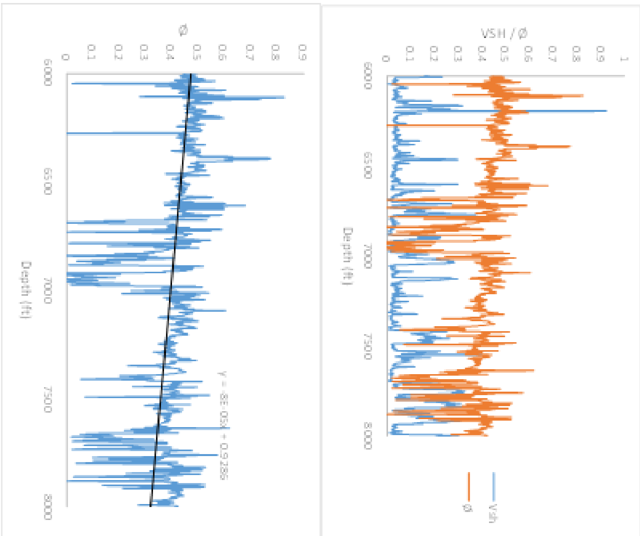

Figure 5: Porosity against Depth and VSH / Porosity against Depth for Well 2

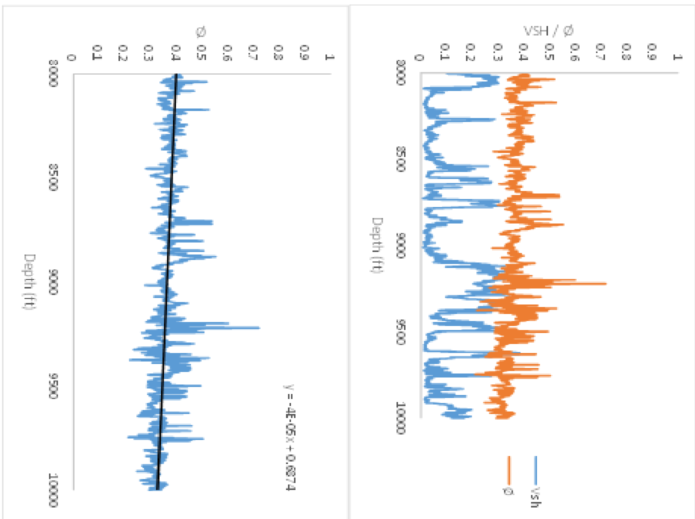

Figure 6: Porosity against Depth and VSH / Porosity against Depth for Well 3

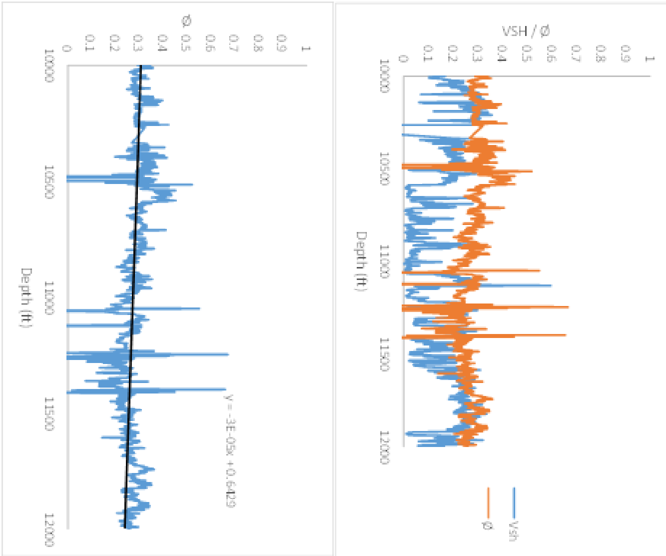

Figure 7: Porosity against Depth and VSH / Porosity against Depth for Well 4

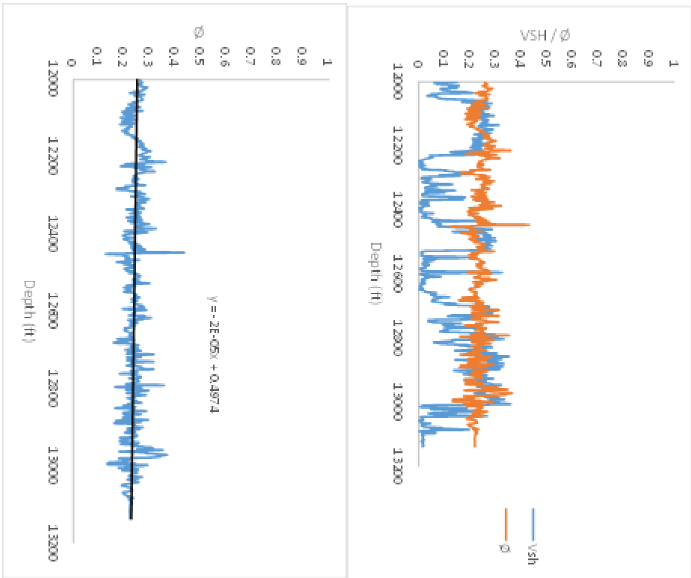

Figure 8: Porosity against Depth and VSH / Porosity against Depth for Well 5

IV. Conclusion

In conclusion, porosity values ranges from 0.013% to 94.08% in the area of study. Porosity decreases with depth in normal compacted formation for the wells. The following porosity equations have been modeled for the study area:

Z = -3E-05$Ø_z$ + 0.5785.This implies that, in the absence of core sample, porosity, φ_z can be estimated at any depth, Z in the area of study. Reservoir thickness is directly related to its porosity. The higher the reservoir thickness, the higher the porosity. Porosity decreases with depth.

References

[1]. **Atwater G I and Miller E E (1965).** The effect of decrease in porosity with depth on future development of oil reserves in South Louisiana. American Association of Petroleum Geologists Bulletin **49** 334.

[2]. **Bachu S and Underschultz J R (1992).** Regional-scale porosity and permeability variations, Peace River Arch Area, Alberta, Canada. American Association of Petroleum Geologists Bulletin**76** 547 – 562.

[3]. **Barker C (1972).** Aquathermal pressuring–role of temperature in development of abnormal pressure zones. American Association of Petroleum Geologists Bulletin **56** 2068– 2071.

[4]. **Beard D C and Weyl P K (1973).** Influence of texture on porosity and permeability of unconsolidated sand. American Association of Petroleum Geologists Bulletin**57** 349 –369.

[5]. **Bjorkun P A and Nadeau P H (1998).** Temperature controlled porosity / permeability reduction, fluid migration and petroleum exploration in sedimentary basins. Australian Petroleum Production Exploration Association Journal**38** 453 – 465.

[6]. **Blackwell D D and Steele J L (1989).** Thermal conductivity of sedimentary rocks: measurement and significance. In: Thermal

History of Sedimentary Basins–Methods and Case Histories, edited by N D Naeser and TH McCulloh (Springer-Verlag, New York) 13–36.
[7]. **Blatt H, Middleton G and Murray R (1980).** Origin of Sedimentary Rocks, 2nd edition, (Printice Hall, Inc., New Jersey) 782.
[8]. **Boswell P G H (1961).** Muddy Sediments (WH Heffer, Cambridge, England) 140.
[9]. **Brigaud F and Vasseur G(1989).** Mineralogy, porosity and fluid control on thermal conductivity of sedimentary rocks. Geophysical Journal International **98** (3) 525–542.
[10]. **Brigaud F Chapman F D S and Douaran S L (1990).** Estimating thermal conductivity in sedimentary basins using lithologic data and geophysical well logs. American Association of Petroleum Geologists Bulletin **74**(9) 1459 – 1477.
[11]. **Bruce C H (1973).** Pressured shale and related sediment deformation, mechanism for the development of regional contemporaneous faults. American Association of Petroleum Geologists Bulletin**57** 878– 886.
[12]. **Calderon J E and Castagna J (2007).** Porosity and lithologic estimation using rock physics and multi-attribute transforms in Balcon Field, Colombia 142- 150.
[13]. **Chukwueke C C Thomas G and Delfaud J (1992).** Sedimentary process, ecstacy, subsidence and heat flow in the distal part of the Niger Delta. Bulletindes Centresde Recherches Exploration-Production Elf-Aquitaine **16**(1) 137– 186.
[14]. **Curtis C D (1978).** Possible links between sand stone diagenesis and depth-related geochemical reactions occurring in enclosing mudstones. Journal of the Geological Society of London**135** 107 – 117.
[15]. **De Boer R B Nagtegaal P J C and Duyvis E M (1977).** Pressure solution experiments on quartzs and. Geochemical et Cosmochimica Acta**41** 257 – 264.
[16]. **Doust H and Omatsola E (1990).** Niger Delta, in Divergent/passive Margin Basins, American Association of Petroleum Geologists Memoir **48** 239 - 248.
[17]. **Dullien F A L (1979).** Porous Media: Fluid Transfer and Pore Structure (Academic Press, New York) 396.
[18]. **Dutta N C (1987a).** Geopressure. Geophysics **67** 2012 - 2041.
[19]. **Dutta N C (2002).** Geopressure prediction using seismic data: current status and the road ahead. Geophysics **67**(6) 2012– 2041.
[20]. **Egeh E U Okereke C S and Olagundoye O O (2001).** Porosity and compaction trend in Okan field (Western Niger Delta) based on well log data. Global Journal of Pure and Applied Sciences **7**(1) 91– 96.
[21]. **Emery K O and Griffiths J C (1953).** Reconnaissance investigation into relationships between behavior and petro graphic properties of some Mississippian sediment. Pennsylvania State University Mineral Industries Experiment Station Bulletin**62** 67 –80.
[22]. **Faust L Y (1953).** A velocity functions including lithologic variations. Geophysics **18** 271–288.
[23]. **Fertl W H (1976).** Abnormal Formation Pressures (Elsevier).
[24]. **Fraser H J (1935).** Experimental study of the porosity and permeability of the clastic sediments. Journal of Geology**43** 910– 1010.
[25]. **Friedman GH and Sanders J E (1978).** Principles of Sedimentology (J. Wiley& sons, New York).
[26]. **Fuchtbauer H (1967).** Influence of different types of diagenesisons and stone porosity. Proceedings of the 7th World Petroleum Congress **2** 353–369.
[27]. **Giles M R and Maxwell J D (1986).** Constraints on the development of secondary porosity in the subsurface: re-evaluation of processes. Marine and Petroleum Geology**3**243 – 255.
[28]. **Graton L C and Fraser H J (1935).** Systematic packing of spheres, with particular relation to porosity and permeability. Journal of Geology **43** 785– 909.
[29]. **Griffiths J C (1964).** Statistical approach to the study of potential oil reservoirs and stones. In: Computers in the Mineral Industries edited by Parks GA (Stanford University Publications in Geological Sciences) **9**637-68
[30]. **Hitchon B, Bachu S, Sauveplane C M and Lytviak A T (1987).** Dynamic basin analysis: an integrated approach with large databases: In: Fluid Flow in Sedimentary Basins and Aquifers, edited by Golf, JC and Williams, BPJ (Geological Society Special Publication) **31** 31 –44.
[31]. **Horsfall O I, Uko E D and Tamunobereton-ariI (2013).** Comparative analysis of sonic and neutron-density logs for porosity determination in the South-eastern Niger Delta Basin, Nigeria. American Journal of Scientific and Industrial Research**4**(3) 261 - 271.
[32]. **Hottmann C E and Johnson R K (1965).** Estimation of formation pressures from log-derived shale properties. Journal of Petroleum Technology**6** 717–722.
[33]. **Hubbert M K and Rubey W W (1959).** Role of fluid pressures in mechanics of over thrust faulting.Geological Society of America Bulletin **70** 115– 166.
[34]. **Hubert M K and Rubey W W (1959).** Role of fluid pressure in mechanics of over thrust faulting, mechanics of fluid-filled porous solids and its application to over thrust faulting. Bulletin of the Geological Society of America **70**(2) 115 – 166.
[35]. **Ikeagwuani F D (1979).** Trends of petroleum exploration in Nigeria, Publication of the Petroleum Inspetorate, NNPC, Lagos.
[36]. **Issler D R (1992).** A new approach to shale compaction and stratigraphic restoration, Beaufort-Mackenzie Basin and Mackenzie Corridor, northern Canada 1170-1189.
[37]. **Kahn J S (1956).** The analysis and distribution of the properties of packing in sand size sediments–1,on the measurement of packing in sandstones. Journals of Geology**64** 385–395.
[38]. **Kharaka Y KandBerry E A E (1976).** Chemistry of waters expelled from sands and sandstones. In: Compaction of Coarse Grained Sediments II edited by Chilingarian G V and Wolf K H (Elsevier, Amsterdam) 41-68.
[39]. **Kogbe C A (1989).** The Cretaceous and Paleocene sediments of southern Nigeria: In: Geology of Nigeria, edited by Kogbe (RockView Limited, Nigeria) 246–276.
[40]. **Martini, I P (1972).** Studies of microfabrics: ananalysis of packing in the Grims by Sandstone (Silurian), Ontario and New York State. Proceedings of the International Geological Congress **6**415 – 423.
[41]. **Maxwell J C (1960).** Experiments on compaction and cementation of sand. In: Rocks Deformation, edited by Griggs D T and Handlin J (GSA Memoir) **79** 105– 132.
[42]. **Maxwell J C (1964).** Influence of depth, temperature, and geologic age on porosity of quartzes sandstone. American Association of Petroleum Geologists Bulletin **48** 697 – 709.
[43]. **Mc Culloh T H (1967).** Mass properties of sedimentary rocks and gravimetric effects of petroleum and natural-gas reservoirs. USGS Professional Papers**528-A**1–50.
[44]. **Middleton M F (1984).** Seismic geohistory analysis-A case history from the Canning Basin, Western Australia.Geophysics**49** 333 - 343.
[45]. **Nagtegaa l P J C (1978).** Sandstone-frame work in stability as a function of burial diagenesis. Journal of the Geological Society of London **135** 101– 105.
[46]. **Ofeke T U (1998).** Subsidence of OMLs 20, 27 and 57 in the Niger Delta from the analysis of well data, Unpubl. M.Sc. Thesis, Department of Physics, Rivers State University of Science and Technology, Port Harcourt, Nigeria.

[47]. **Ofoegbu C O (1985).** A review of the geology of the Benue Trough, Nigeria. Journal of African Earth Sciences **3**283– 291.

[48]. **Okiongbo K S (1998).** Determination of overpressure in Kwale oil field (OML60) in northern Niger Delta, using vertical seismic profile (VSP) techniques, Unpublished M.Sc. Thesis, Department of Physics, Rivers State University of Science and Technology, Port Harcourt, Nigeria.

[49]. **Powers M C (1953).** A new roundness scale for sedimentary particles. Journal of Sedimentary Petrology **23** 117– 119.

[50]. **Renton J J Heald M T and Cecil C B (1969).** Experimental investigation of pressure solution of quartz. Journal of Sedimentary Petrology **39** 1107 –1117.

[51]. **Rittenhouse G (1943).** A visual method of estimating two-dimensional sphericity. Journal of Sedimentary Petrology**13** 79 – 81.

[52]. **Robinson R B (1966).** Classification of reservoir rocks by surface texture. American Association of Petroleum Geologists Bulletin **50** 547– 559.

[53]. **Scherer M (1987).** Parameters influencing porosity in sandstones: A model for sandstone porosity prediction. American Association of Petroleum Geologists Bulletin **71**(5) 485– 491.

[54]. **Schlumberger (1972).** Log Interpretation : Principle (Schlumberger Limited, Park Avenue, New York) **1**1-45.

[55]. **Schlumberger (1985).** Well Evaluation Conference (Schlumberger Technical Services, Inc., Park Avenue, New York) **2** 113-124.

[56]. **Schmidt G W (1973).** Interstitial water composition and geochemistry of deep Gulf coasts have sandstones. American Association of Petroleum Geologists Bulletin**57**(2) 321–337.

[57]. **Schmidt V Mc Donald D A Platt R L (1977).** Pore geometry and reservoir aspects of secondary porosity in sand stones. Bulletin of Canadian Petroleum Geology **25** 271 –290.

[58]. **Selley R C (1978).** Porosity gradients in North sea oil-bearing sandstones. Journal of the Geological Society of London **135** 119–132.

[59]. **Selley R C and Morrill D C (1983).** The Reservoir, International human resources development corporation, U. S.A.

[60]. **Selly R C (1982).** Introduction to Sedimentology, 2nd edition (Academic Press, London) 475.

[61]. **Short K C and Stauble A (1967).** Outline of Geology of Niger Delta. America Association of Petroleum Geologists Bulletin **51** 761 - 779.

[62]. **Surdam R C, Boese S W and Crossey L J (1984).** The chemistry of secondary porosity .In: Clastic Diagenesis edited by McDonald DA and Surdam RC (AAPG Memoirs) **37**127– 149.

[63]. **Telford W M Geldart L P and Sheriff R E(1976).** Applied Geophysics 2nd edition (Cambridge University Press).

[64]. **Tickell F G and Hiatt W N (1938).** Effect of angularity of grain on porosity and permeability of unconsolidated sands. America Association of Petroleum Geologists Bulletin **22** 1272– 1274.

[65]. **Udo, K.I., Akpan, M.J., Agbasi, O.E (2015).** Estimation of Overpressure in Onshore Niger Delta Using Wire-Line Data. International Journal of Science and Research, Vol 4, Issue 5, pp. 2278 – 2784.

[66]. **Uko E D Ekine A S Ebeniro J O and Ofoegbu C O (1992).** Weathering structure of east central Niger Delta, Nigeria. Geophysics **57**(9) 1228– 1233.

[67]. **Uko E D Emudianughe J E and Tamunobereton-ariI (2013).** Overpressure prediction in the north-west Niger Delta, Using Porosity Data. Journal of Applied Geology and Geophysics **1**(3) 42 - 50.

[68]. **Von Engelhardt W (1960).** derPorenraum der Sedimente (Springer-Verlag, Berlin) 207.

[69]. **Weber K J and Daukuru E M (1975).** Petroleum geological aspects of the Niger Delta. Journal of Mining Geology **12** 9 –12.

[70]. **Whiteman A (1982).** Nigeria: Its Petroleum Geology, Resource and Potential (London).

[71]. **Wolf K H and Chilingarian G V (1976).** Diagenesis of sandstones and compaction. In: Compaction of Coarse Grained Sediments II edited by Chilingarian G V and Wolf K H (Elsevier, Amsterdam) 69-444.

[72]. **Wylie A S Jr (2002).** Log curve amplitude slicing: Visualization of well log. Amplitudes for paleogeographic reconstruction of the Middle Devonian Traverse Group, Michigan Basin. Ann Arbor, United States.

[73]. **Wyllie M R J Gregory A R and Gardner G H F(1958).** An experimental investigation of factors affecting elastic wave velocities in porous media. Geophysics **23** 459 –493.

[74]. **Wyllie M R J Gregory A R and Gardner L W (1956).**Elastic wave velocities. Geophysics**21** 41 –70.