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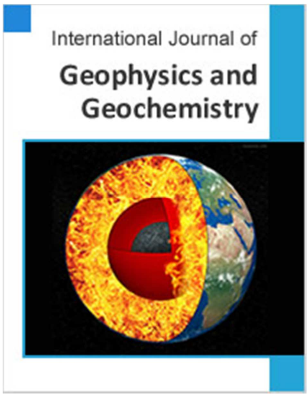

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Petrographic, Well Logging and Well Log Analysis of a Wellbore at Umueze in Orlu, Southeastern Nigeria

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Abstract

This report presents the log analysis results from a well at Umueze in Orlu, South-eastern Nigeria. The Resistivity and Spontaneous Potential log analysis indicates that the upper cretaceous and tertiary formations have very high porosities, up to 37% and very low water saturation. The water resistivities calculated from the 3 different water zones gave consistent values, between 0.12 and 0.15 Ωm, which is consistent with resistivities from the catalog for that area.

1. Introduction

This paper shows the results from the logging and interpretation of two sets of logs (Resistivity and SP) at Umueze in Orlu, Southeastern Nigeria (Figure 1). The log analysis is intended to support reservoir evaluation [1]. The upper cretaceous and tertiary formations are good reservoirs currently producing underground water in the area [2], and are the main exploration targets of the survey. The general purpose of well log analysis is to convert the raw log data into estimated quantities of oil, gas and water in a formation [3]. A review of the general stratigraphy of the area is presented, focusing on the two target formations, followed by the petrophysical analysis of logs from a well in the area. Permeabilities, productivity and reserves are calculated for several zones of interest.

Logging generally means to “make a record” of something. Well logging, or borehole logging entails making a detailed record (a well log) of the geologic formations penetrated by a well. The log could be based on visual inspection of cuttings or core logs (geological logs) brought to the surface or by geophysical logs where physical measurements are made by lowering an instrument into a hole. While geophysical logging in petroleum is done to determine porosity and hydrocarbon saturation, in geothermal, the main emphasis is on location of fractures and recording of physical parameters e.g. temperature and pressure. Well logging is done during all phases of geothermal development; drilling, completion, production and abandonment [4].

2. Methods

Two types of logging were done, the Resistivity log SP log.

2.1. Resistivity Logs

Resistance is impedance to flow of current and is a function of geometry and intrinsic resistivity of the material. Resistivity is the inverse of conductivity. Current flow in porous rock is mainly through the fluid filling the pore space and is affected by pore volume, pore connectivity and pore fluid composition, degree of alteration and mineralogy and temperature. Pore space character varies from formation to formation and for this reason, resistivity logs are often useful for exploring lithological units [4].

2.2. Self Potential (SP) Logs

Schlumberger developed the SP method to measure small potential differences between the downhole movable electrode and the surface earth connection. The potentials arise from electrochemical and electrokinetic processes and are typically in the range of a few mV to a few tens of Mv.

2.3. Stratigraphy of the Area

The stratigraphic succession in Anambra Basin is given in Table 1. The geological formations that outcrop in the area include Benin Formation, Ogwashi Asaba Formation, Ameki Formation, Imo shale, Nsukka Formation and Ajalli Sandstone (upper Maastritchian) Figure 2.

Table 1. *Stratigraphic Succession in Anambra Basin [5].*

Age Epoch	Age	Formation	Lithology
	Miocene-recent	Benin Formation	Medium-coarse grained, poorly consolidated sands with clay lenses and stringers.
Tertiary	Oligocene-miocene	Ogwashi Asaba Formation	Unconsolidated sands with lignite seams.
	Eocene	Ameki Formation	Grey clayey sandstones and sandy clay sandstones.
	Paleocene	Imo Shale	Laminated clayey shales.
	Upper Maastritchian	Nsukka Formation	Sandstones Intercalating with shale.
		Ajalli Sandstone	Poorly Consolidated sandstones typically cross bedded with minor clay layers.
Upper Cretaceous	Lower Maastritchian	Mamu Formation	Shale, Sandstones, Mudstones and Coal Seams.
Lower Cretaceous	Campanian	Nkporo/Enugu Shale	Dark grey shale, Clayey shale with clay lenses.
	Santonian	Awgu Formation	Bluish grey shale with clay lenses.
	Turonian	Ezeaku Formation	Black shale with clay and limestone lenses.

2.4. Geology of the Area

The area is a part of Anambra Basin whose rocks are upper cretaceous in age [5]. It lies within latitude 05^0 47^i 686^{ii} N and longitude 007^0 03^i 716^{ii} E and covers an area of about $110km^2$.

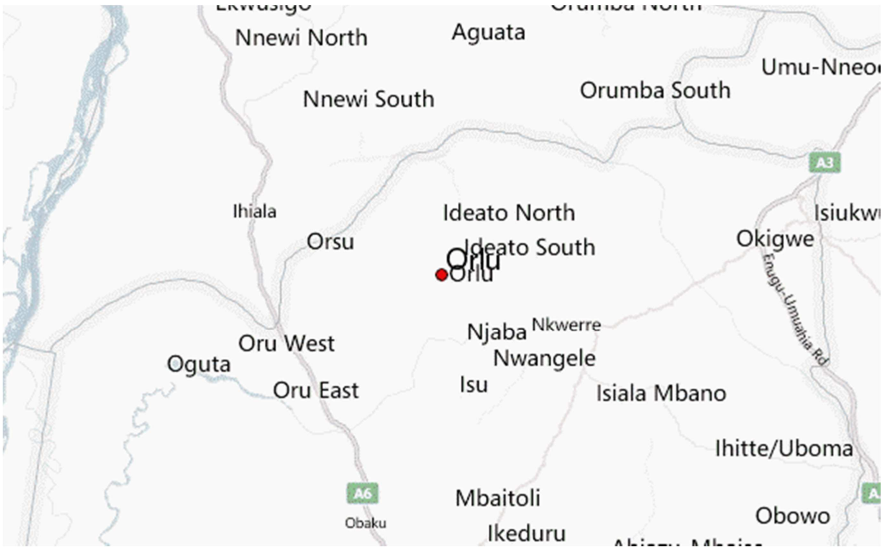

Figure 1. *Location map of the study area [6].*

The study area is within Ihioma, Umuhu-Okabia and Ubaha in Orlu area of Imo State, Southeastern Nigeria (Figure 1). Ihioma, Umuhu-Okabia and Ubaha are underlain by the Ogwashi-Asaba Formation (the Lignite Series) which is Upper Eocene in age. The Formation consists of variable sequence of clay, sandstones and thick seams of lignite. The thickness of the lignite seams is more than 6m in some areas [5]. The Ogwasi-Asaba Formation is only known from isolated outcrops and in boreholes [5].

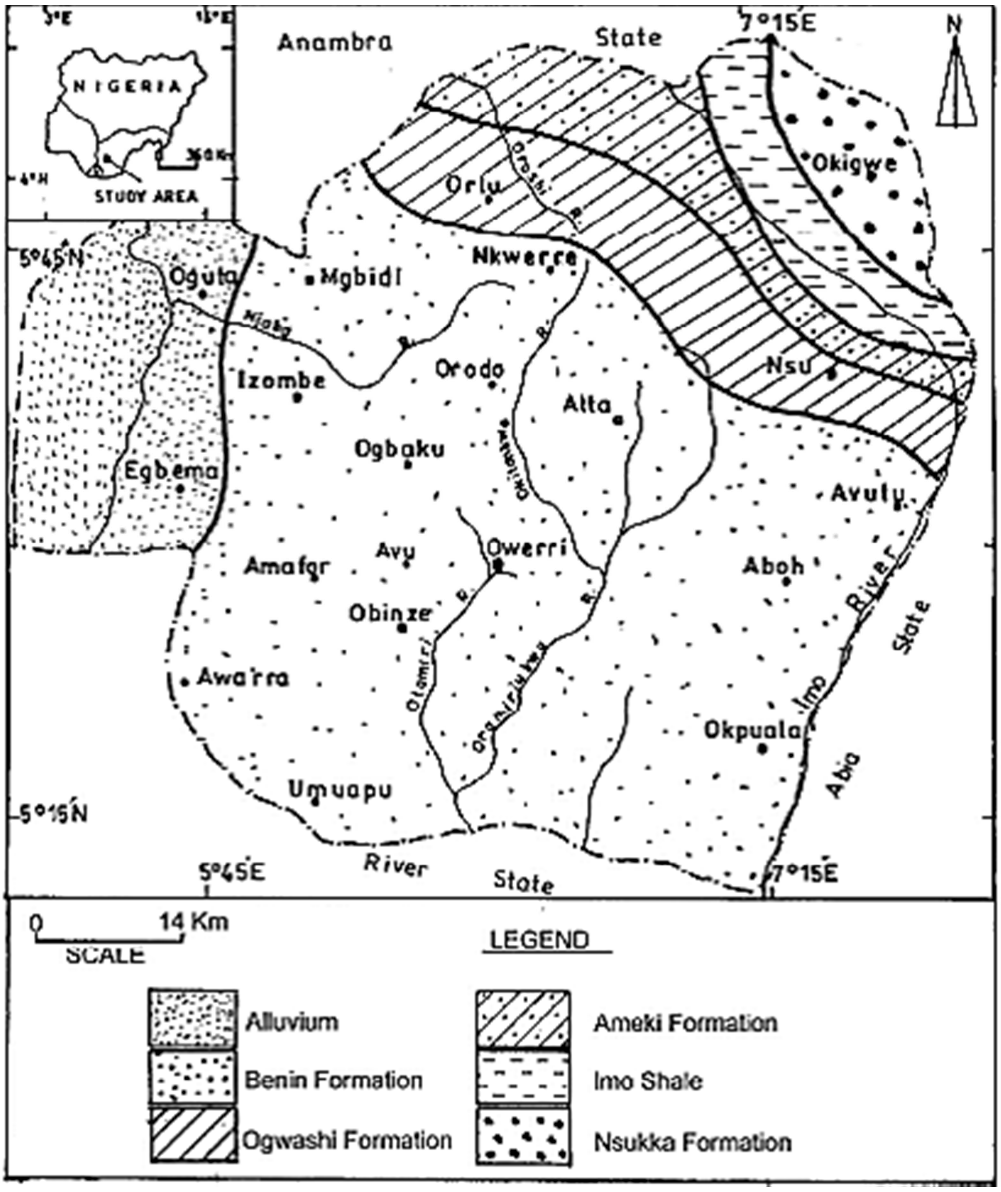

Figure 2. *Location/geology map.*

2.5. Well Log Data

A suite of logs from the well in the area was made from logging data (table 2) obtained by KECK RESISTIVITY METER for this study. One well was available for this study with a suite of logs, spontaneous potential (SP) and resistivity. The well is located within sand channels of the area and is producing underground water (Figure 3). Figures 4 show the logs for the well over the interval of interest. In the well, there is a sharp decrease in the GR and SP curves at the top indicating clean and permeable zones. The photoelectric factor was found to be around 2, this is an indication that the dominant lithology is sandstone [7]. Another interesting effect is seen at the top of the Ogwashi Asaba sand, where there is a sharp increase on the S-wave velocity but almost no change on the P-wave velocity, probably due to the lithologic change between sand and shale, which is seen by the S-wave but not the P-wave [8].

Table 2. *Well log data.*

DEPTH (ft)	SP (2.5)mV	SP (0.25)mV	R (2.5)ohm-m	R (0.25)ohm-m
SS80		033	1000	1000
90	040	049	809	1000
100	013	001	641	972
110			349	718
130	023	013	026	050
140	030		029	050
150	011	-001	029	065
160	003	-001	032	056
180	-011	008	031	055
200	012	0	028	049
220	013	007	030	045
240	013	019	030	044
260	020	029	029	049
300	021	034	034	046
315	027	048	031	041

Log data for this project is relatively sparse:

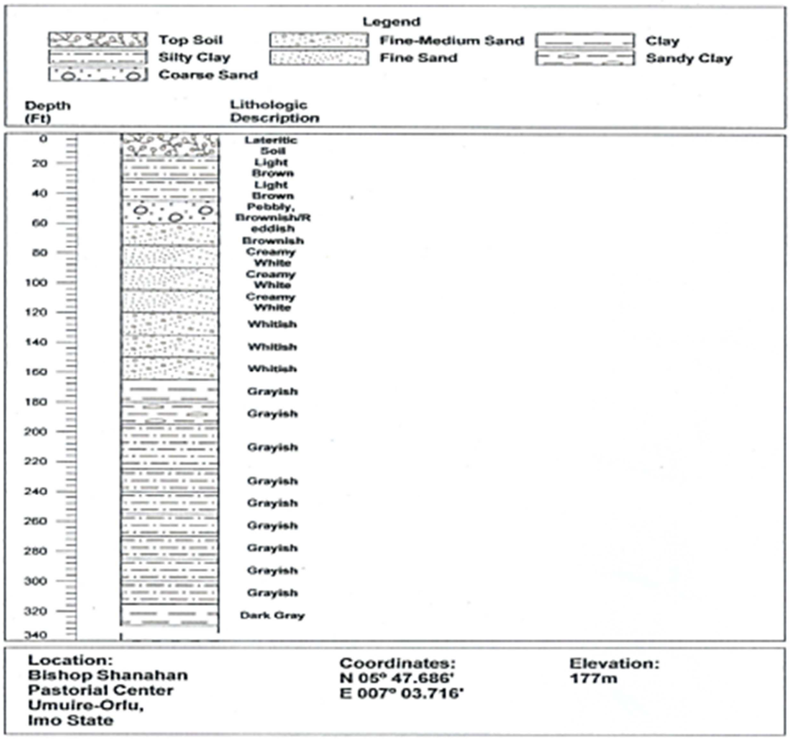

Figure 3. Lithology through depth.

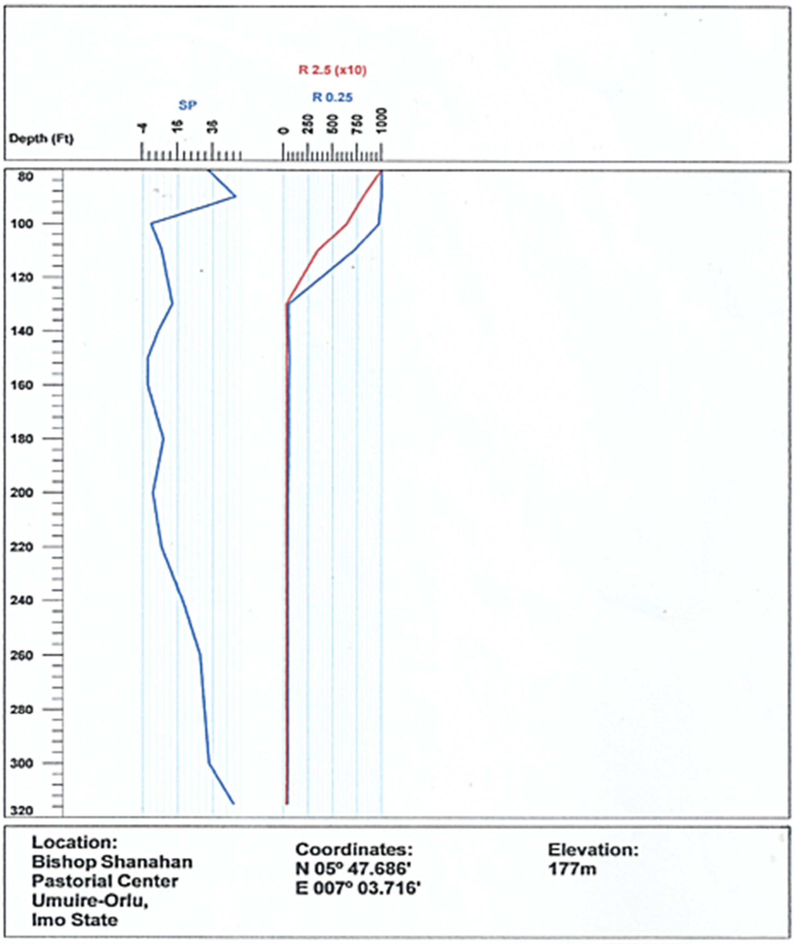

Figure 4. SP and Resistivity log from well.

2.6. Log Analysis

The first step in the log analysis was to identify the zones of interest (clean zones with Hydrocarbons or water reservoirs), and define clean and shale baselines on the logs [9]. The formation sand is clearly identified in the well by a significant deviation to the left in the Resistivity logs, as we pass from the lateritic and top soil to the reservoir sands of the tertiary member. The depth of this sand reservoir is between 130ft and 330ft with very low resistivity and high porosities. The zones of interest for the petrophysical interpretation were defined in terms of clean zones with a water zones used to calculate water resistivity at formation temperature, which is necessary to calculate water saturation and permeability.

The clean and shale lines were marked on the logs and estimation of shale volume followed next. The shale volume (V_{sh}) for this study was calculated using spontaneous potential (SP).

$$V_{shs} = SP - SP_{clean}/SP_{shale} - SP_{clean} \quad (1)$$

SP is the picked log values, while clean and shale indicate values picked in the clean and shale base lines, respectively.

To calculate water saturation, most methods require a water resistivity (R_w) value. In this case, an obvious clean water zone is present in two of the wells in the area and water resistivity in this zone was calculated from the porosity and resistivity using the Ro method given by the formulae:

$$RW\ @\ FT = PHI_{wtr}\ {}^{m}Ro/a \quad (2)$$

RW@FT is the water resistivity at formation temperature, PHI_{wtr} and Ro are the total porosity and deep resistivity values in the water zone, ‘a’ is the tortuosity factor and ‘m’ is the cementation exponent.

Archie’s method was used to calculate water saturation (Swa) using the equation below:

$$S_{wa} = (RW@FT/R_{wa})^{I/N} \quad (3)$$

where n is the saturation exponent and Rwa is water resistivity in the zone of interest, calculated in the same manner as RW@FT:

$$R_{wa} = PHI_t^m * RESD/a \quad (4)$$

Since RW@FT is equal to Rwa, saturation in the water zone should be equal to 1

The parameters a, m and n were set to usual values for unconsolidated sandstones, 0.62, 2.15 and 2, respectively [3]. These parameters could also be determined from core analysis.

Permeability (Perm) is calculated using the Wyllie-Rose method considering Morris- Biggs parameters, which is generally used when no core data is available:

$$PERM_w = CPERM * (PHI_e)^{DPERM}/(SW_w)^{EPERM} \quad (5)$$

SW_{ir} is the irreducible water saturation. CPERM, DPERM and EPERM are constants, which should be adjusted by core calibration. In this study, Morris-Biggs values (65000, 6 and 2, respectively, for the oil-saturated zoned and 6500, 6 and 2 for the gas-saturated zones) where used in place of the constants. SW_{ir} is equivalent to S_{wa} (water saturation) from Archie’s equation.

Finally, the productivity and reserves of the intervals of interest are estimated, along with an estimated flow rate. These values can be used as a control to compare the quality of wells from similar reservoirs even without the results being calibrated [10].

3. Results and Discussions

The previous methodology was applied to the zone of interest defined in the well. The zone corresponded to reservoir sand in the tertiary sediments [11]. A water zone was also interpreted in the well, and was used to calculate water resistivity. Low resistivity with moderate to high porosity indicates water or shale.

When:

Rmf > Rw there is a negative deflection indicative of permeable zones.

Rmf < Rw, there is a positive deflection indicative of permeable zones too.

Rmf = Rw, the log response is on the shale baseline, not indicative of permeable zones.

It should however be noted that the SP log response is a function of the differences in resistivities of mud filtrate (Rmf) and formation water (Rw) and not due to the amount of permeability. The difference in resistivities is brought by about salinity differences in the mud filtrate and formation water.

4. Conclusions

Log character and borehole condition reveal low resistivity and low SP, an indication of a reservoir/water bearing body.

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