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Redefining fluids relative permeability for reservoir sands. (Osland oil and gas field, offshore Niger Delta, Nigeria)

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ABSTRACT

Redefining oil and water relative permeability for the evaluation of reservoir sands, a case study of Osland oil and gas field, Offshore Niger Delta, Nigeria has been carried out. The aim of this study is to modify water relative permeability (K_{wr}) and oil relative permeability (K_{or}) equations in sandstone units. The objectives are to provide alternative expressions for K_{wr} and K_{or} in sandstone units, use the equations as inputs in a simplified water cut (C_w) equation to predict the volume of water that will be associated with the recoverable volume of oil (V_{Ro}) in penetrated reservoirs. The relationship between porosity (Φ) and water saturation (S_w), with the relationship between porosity and hydrocarbon saturation (S_h), were used to evaluate K_{Wr} and K_{or} in order to predict C_w in the selected reservoirs. Reservoir X in Well D_1 shows about 2.0×10^6bbl for V_{Ro} and 18.78% for C_w but in D_2 it shows about 7.4×10^6bbl and 1.73% for V_{Ro} and C_w respectively. Similarly, in Reservoir Y, D_1 has about 6.8×10^6bbl of V_{Ro} and 0.034% of C_w, but in D_2 it has about 9.3×10^6 bbl of V_{Ro} and 0.015% of C_w. The results suggest that high Φ with corresponding high S_w resulted in high associated C_w in Reservoir X. The evaluation also confirmed that the decrease in the ratio of oil relative permeability to water relative permeability (K_{or}/K_{wr}) corresponds to the increase in C_w. The total recoverable volumes of hydrocarbons from the two wells are estimated at 7.7×10^9cu.ft for gas and at 2.54×10^7bbl for oil. With the present conditions of the two reservoirs, the values of C_w in Reservoir X are low and are extremely low and negligible in Reservoir Y. Reservoir X in Well D_1 has a smaller volume of V_{Ro} but the C_w is higher than others. Nonetheless, the C_w in Reservoir X is still within acceptable range.

1. Introduction

This study focuses on the Osland oil and gas field, offshore Niger Delta, Nigeria. One of the evaluated reservoirs has a significant percentage of water saturation. This raised questions on the reservoir's water cut (C_w) because sometimes it could be problematic, especially when the transition zone is reached.

Water cut is defined as the ratio of water produced compared to the total volume of fluid produced (Schlumberger, 2016). Wire-line logs with 3-D data were engaged in this work. Previous works (Emujakporue et al., 2012; Richardson, 2014; Nwankwo et al., 2015; Adagunodo et al., 2017) have shown successes with the use of petrophysics and seismic interpretation in the region for different objectives.

Herein, information from logs and seismic models were combined with redefined expressions for oil relative permeability (K_{or}) and water relative permeability (K_{wr}) to aid the estimation of C_w. Water viscosity (μ_w) and oil viscosity (μ_o) are also important parameters in this evaluation. According to Schlumberger (1989), the rate of water production is dependent upon relative permeability ratio (K_{or}/ K_{wr}) and viscosity ratio (μ_w/μ_o).

Crain's Petrophysics (2015) stressed that interest is always in the volume of oil that can be pumped out of reservoirs, possibly without any associated water production. Oilfield Review (Spring, 2000), also stated that in some depleting reservoirs, for every one barrel of hydrocarbon produced, 3 barrels of associated water is also produced. The technologies for water control are quite expensive and tedious, therefore, there is need to be aware of the volume of water that will be associated with hydrocarbon production in the reservoirs before exploitation activities began.

Schlumberger (1989) and Crain's Petrophysics (2015) have shown equations involving irreducible water saturation (S_{wirr}) and reservoir water saturation (S_w) for the estimation K_{or} and K_{wr}. S_{wirr}

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is dependent upon porosity (Φ) which is fundamental to qualitative and quantitative evaluations. Hence, when Φ it is not approximated over a range of equations, it could present a way of optimising it relevance and reducing errors concerning overestimation and/or underestimation of the dependent parameters (Richardson and Taioli, 2017). Therefore, in this research work, the expressions for K_{or} and K_{wr} were modified for sandstone units, such that equations involving Φ with water saturation (S_w) and hydrocarbon saturation (S_h) were presented.

These equations were engaged with the direct computation of Φ, to predict K_{or}, K_{wr} and the associated volumes of C_w in the reservoirs across the wells. Apart from the suggestion of alternative expressions for some of the relevant parameters (K_{or} and K_{wr}) herein to aid the determination of C_w in sandstone units, the results of this research will help the decision to go ahead with exploitation activities in the studied field. This can serve as a way to reduce risk and uncertainty because oil and gas ventures are usually not undertaken without attaining levels of certainty, regarding the occurrence and recoverable volumes of hydrocarbons and associated water production in the selected reservoirs. Qualitative and quantitative evaluation of reservoirs using integrated wire-line logs and seismic data were carried out.

2. Study location and brief geology

The location of study (Osland) is within Latitude 5.5°N and 5.7°N and Longitude 5.0°E and 5.2°E, in the offshore area of southwestern Niger Delta (Fig. 1). Niger Delta is defined by three lithostratigraphic units; Benin, Agbada and Akata Formations (Weber and Daukoru, 1975: Evamy et al., 1978: Ejedawe, 1981).

Faulting and other deformations in the Niger Delta are linked with the continental breakup and rifting of the African and South American plates (Genik, 1993; Michael and Ronald, 2006). Rifting in the region took effect from Late Jurassic to late Cretaceous, after then; gravity tectonism emerged as a principal force and induced other forms of structural alterations (Lehner and De Ruiter, 1977; Genik, 1993; Michele et al., 1999; Rowan et al., 2004). The Gravity tectonics was active within the Akata formation, but it stopped prior to the deposition of the Benin Formation. Diapirs, rollover anticlines, collapsed crests and faults are closely associated with this gravity tectonics (Doust and Omatsola, 1990; Stacher, 1995; Brownfield, 2016).

Freddy et al. (2005) confirmed that the structures are exemplary of an extensional rift system with faults juxtaposing against each other. The diapiric shale within the Niger Delta basin provides the trap (seal and cap rock) in the region (Doust and Omatsola, 1990). The shale also provides three sealing mechanisms; clay smear along faults, interbedded sealing units against which reservoir sands are juxtaposed due to faulting and vertical seals (Doust and Omatsola, 1990; Freddy et al., 2005). The degrees of overpressure in the region are also closely related to the inability to de-water because of the rapid sedimentation of fine-grained sediments.

3. Materials and methods

3.1. Materials

Seismic Micro-Technology (SMT) software was used for the interpretation of data. The set of data for this study comprised 3-D seismic data, a suite of geophysical wire-line logs: gamma ray(GR), deep laterolog (LLD), shallow laterolog (LLS), water saturation (S_w), neutron (NPHI) and bulk density (RHOB) logs from two wells. SEG – Y data comprising of 38 in-lines and 32 cross-lines was engaged. Check shot data was used to convert seismic travel time values to depths and to tie well logs to seismic sections.

3.2. Methods

The major steps involved are;

(a) modification of the relevant equations for sandstone units,
(b) log and seismic interpretation to help derive porosity, water saturation reservoirs thicknesses, and drainage areas which are essential inputs for the expressions in (a) above and volumetric estimations and

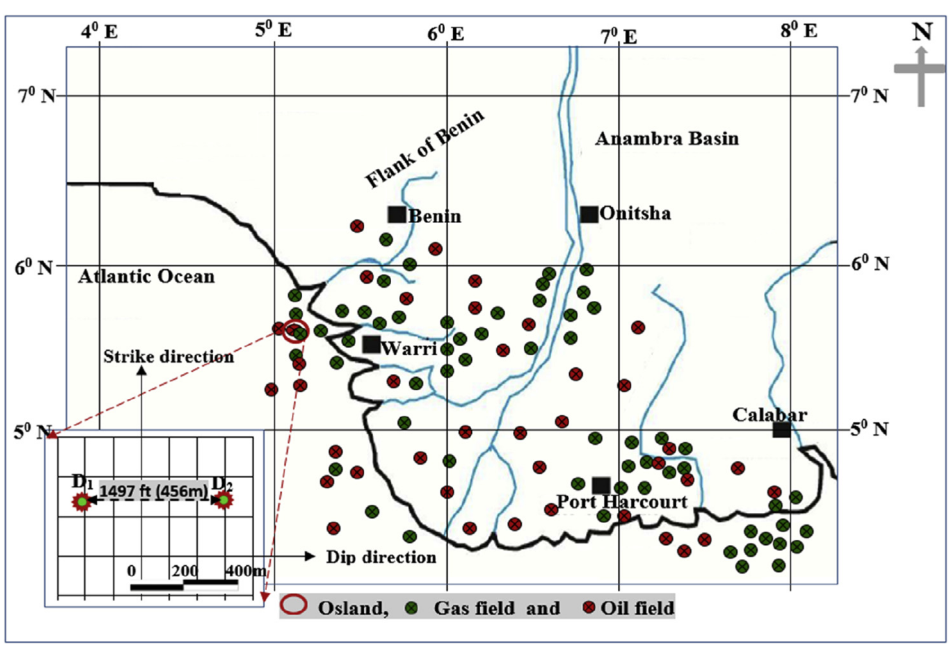

Fig. 1. Map of Niger Delta showing oil and gas fields and study location.