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Reservoir characterization and seal integrity of Jemir field in Niger Delta, Nigeria

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ABSTRACT

Ignoring fault seal and depending solely on reservoir parameters and estimated hydrocarbon contacts can lead to extremely unequal division of reserves especially in oil fields dominated by structural traps where faults play an important role in trapping of hydrocarbons. These faults may be sealing or as conduit to fluid flow. In this study; three-dimensional seismic and well log data has been used to characterize the reservoirs and investigate the seal integrity of fault plane trending NW-SE and dip towards south in Jemir field, Niger-Delta for enhanced oil recovery. The petrophysical and volumetric analysis of the six reservoirs that were mapped as well as structural interpretation of the faults were done both qualitatively and quantitatively. In order to know the sealing potential of individual hydrocarbon bearing sand, horizon–fault intersection was done, volume of shale was determined, thickness of individual bed was estimated, and quality control involving throw analysis was done. Shale Gouge Ratio (SGR) and Hydrocarbon Column Height (HCH) (supportable and structure-supported) were also determined to assess the seal integrity of the faults in Jemir field.

The petrophysical analysis indicated the porosity of traps on Jemir field ranged from 0.20 to 0.29 and the volumetric analyses showed that the Stock Tank Original Oil in Place varied between 5.5 and 173.4 Mbbl. The SGR ranged from leaking (<20%) to sealing (>60%) fault plane suggesting poor to moderate sealing. The supportable HCH of Jemir field ranged from 98.3 to 446.2 m while its Structure-supported HCH ranged from 12.1 to 101.7 m.

The porosities of Jemir field are good enough for hydrocarbon production as exemplified by its oil reserve estimates. However, improper sealing of the fault plane might enhance hydrocarbon leakage.

1. Introduction

Oil and gas resources sourced mainly from Niger Delta had accounted for 80% of the Nigerian government's revenue and 95% of the country's export earnings since 1970s. However, there have been some irregularities recorded in the recent time from the exploration and production companies in Niger Delta, such as dry wells or unbalanced record of oil reserves. Till date twenty-three oil fields have been shut in or abandoned as a result of poor prospectivity or total drying up of the wells (Oil and Gas, 2015). The need to thoroughly evaluate prospects so as to determine optimal production strategies and also minimize risk that may be associated with hydrocarbon exploration has driven the development of an array of techniques which attempt to propagate log properties (Formation evaluation). These include the use of deterministic and linear physical relationship between log properties and the corresponding seismic response of subsurface rock units (e.g. Muslime and Moses, 2011; Eshimokhai and Akhirevbulu, 2012) as well as reservoir characterization (Schlumberger, 1989; Eshimokhai and Akhirevbulu, 2012). However, sequel to estimation of petrophysical parameters and oil reserves in a field; it is paramount to analyze the sealing potential (seal integrity) of the fault supporting the trap in order to know whether the rock structure is capable to keep oil and gas from migrating out of the trap or not.

Seal integrity is the analysis of substance that forms barrier in

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fault. Fault plays an important role in creating hydrocarbon traps because it serves as house which hydrocarbon lives. Seals are fundamental (i.e. no seal no trap). Seals also control the movement of hydrocarbons during production. Faults that do not form seal may prevent oil and gas from accumulating in the subsurface. Open and permeable faults in reservoir may also cause serious lost-circulation problems during drilling operations (Oniyangi, 2008). Consequently, if fault leaks; they provide field-wide communication among numerous fault compartments. Thus, ignoring seal integrity of fault plane and depending solely on reservoir parameters and estimated hydrocarbon contacts can lead to extremely unequal division of reserves.

Reservoirs characterization have been done on many fields of Niger Delta (Eshimokhai and Akhirevbulu, 2012; Ameloko and Omali, 2013; Oyedele et al., 2013; Oyeyemi and Aizebeokhai, 2015) but few have been reported about seal integrity – a gap that is essential to be filled in order to enhance the recovery and improve the reserve portfolio. Hence the current study was aimed to characterize the reservoirs and investigate the seal integrity of reservoirs for enhanced oil recovery of Jemir field in Niger-Delta, Nigeria. The specific objectives of the study include identification of structural trap, estimation of petrophysical parameters and volume of hydrocarbon reserves, establishment of throw distribution across the interpreted fault-dependent structures, determination of Shale Gouge Ratio (SGR) and Hydrocarbon Column Height (HCH) (supportable and structure-supported). The determination of SGR is hinged on its suitability to predict the sealing capacity of faults (Yielding et al., 1997) as faults with sand-rich gouge tend to leak; whereas faults with shale-rich gouge tend to seal. The HCH will estimate the likely hydrocarbons' height that a fault can support because fault does not only control how much hydrocarbons are in a trap, but also the vertical distribution of hydrocarbons among a series of stacked sands.

2. Location and geology of the study area

Jemir field is an offshore field located in the western region of Niger Delta: one of the Nigerian sedimentary basins (Fig. 1). The field has total coverage of 113.2 km^2. The Niger-Delta which covers an area of about 75,000 sq km is situated in southern Nigeria between latitudes 4° N to 7° N and longitude 5° E to 8° E (Fig. 2). It is bounded to the west and northwest by the western African shield,

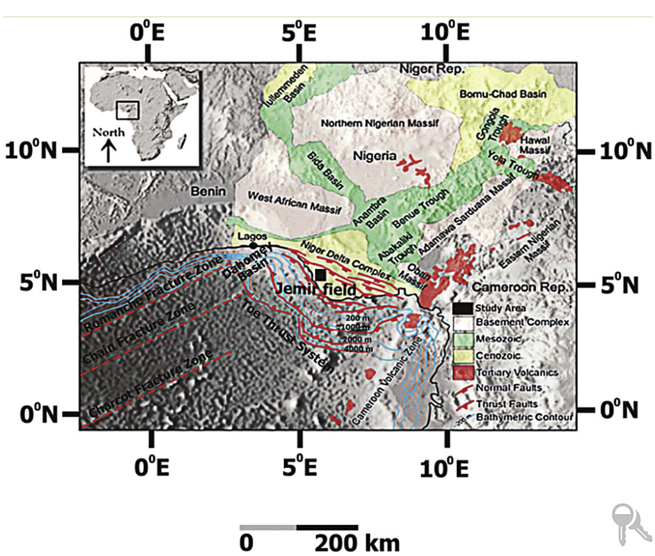

Fig. 1. Map of Niger-Delta showing the study area.

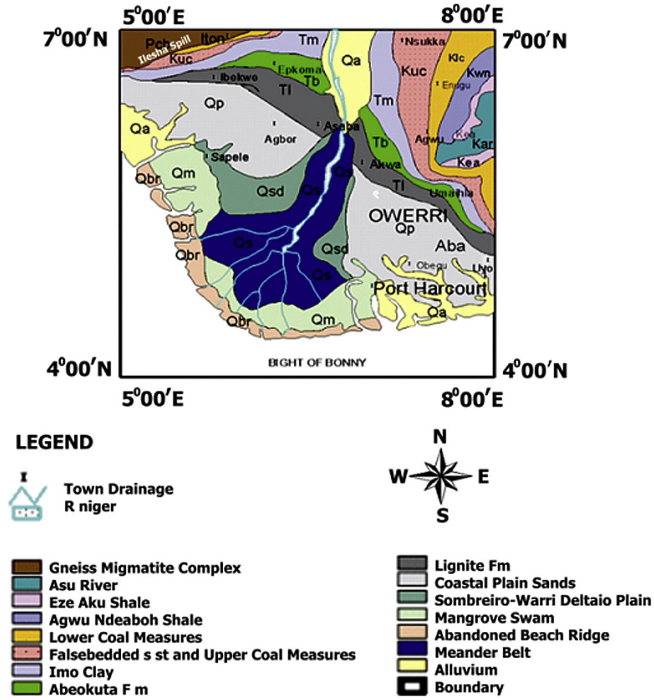

Fig. 2. Geological map of Niger-Delta (adapted from Amadi et al., 2012).

which terminates at the Benin hinge line; to the east by the Calabar hinge line; to the north by the Anambra basin and Abakaliki anticlinorium; and to the south by the gulf of Guinea (Oyedele et al., 2013). It extends in an East-West direction from South-West Cameroun to the Okiti-pupa Ridge with its apex situated south-east of the confluent of the Niger and Benue Rivers.

Jemir field is geologically concealed within Tertiary section of the Niger Delta comprising three Formations: Benin, Paralic Agbada and pro-delta Marine Akata Formation representing prograding depositional facies distinguished mostly on the basis of sand-shale ratio (Short and Stauble, 1967; Doust and Omatsola, 1990; Kulke, 1995; Ameloko and Omali, 2013). The Benin Formation is a continental latest Eocene to Recent deposit of alluvial and upper coastal plain sands. It consists predominantly freshwater baring massive continental sands and gavels deposited in an upper deltaic plain environment. The Agbada Formation consists paralic siliciclastics, which underlies the Benin Formation. It consists fluviomarine sands, siltstones and shales. The sandy parts constitute the main hydrocarbon reservoirs. The grain size of these reservoir ranges from very coarse to fine. The Akata Formation is the basal unit of the Tertiary Niger Delta complex. It is of marine origin and composed of thick shale sequence (potential source rock), turbidite sands (potential reservoirs in deep water) and minor amount of clay and silt.

Doust and Omatsola (1989) documented that normal faults activated by the movement of deep seated, ductile, overpressured marine shale have marred greatly the Niger Delta clastic wedge. Most of these faults developed during delta progradation were syndepositional and also affect sediment dispersal. Fault growths usually coexist with slope instability towards the continental margin. Structural complexity in a local region reveals the density and fault style of such region. Simple structures such as crestal and flank are also present along individual faults. Hanging wall rollover anticlines are formed as a result of listric-fault geometry and differential loading of sediments of delta above ductile shales. Many complex structures that are cut by large number of faults with series of thrown include collapsed crest structures with domal shape