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REVIEW ARTICLE

STRUCTURAL INTERPRETATION OF ASSA-FIELD RESERVOIR IN NORTHERN NIGER DELTA NIGERIA, USING WELL LOG

Chukwu, C. Ben[a*], Udota, S. Benjamin[b]

[a] *Department of Physics, Faculty of Science, Rivers State University, Port Harcourt, Nigeria.*
[b] *Department of Geology, Faculty of Science, Rivers State University, Port Harcourt, Nigeria.*
** Corresponding author's email: benedict.chidi@yahoo.com*

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ABSTRACT

Structural interpretation and characterization of Assa-field in Northern Niger Delta was done to map the primary structures responsible for hydrocarbon entrapment and closures that are favorable for the accumulation of hydrocarbon as well as to indicate areas for hydrocarbon exploration in the field. The method used for this research involved delineation of lithology, identification of reservoir, interpretation of horizon and fault to generate structural maps of the subsurface. Depth and time structure maps were generated to show more detailed structure of the field. Three major horizons (sand 1, sand 2, and sand 3) were mapped based on uniqueness and clarity of their features. Major faults were delineated from the 3-D seismic section. The appearance of these faults in the field is a sign of possible hydrocarbon accumulation. The knowledge from the results of this study can be applied in exploration and production to identify hydrocarbon trapping potential of a field and volumetric evaluation of fluid in a field.

KEYWORDS

Reservoir, Fault, Horizon, Assa-field, Trap

1. INTRODUCTION

The need to provide basic structural shelters especially in Island settings Hydrocarbon reservoirs are found in geologic traps as defined by Wan Qin (1995) as any combination of rock structure that is capable of preventing the leakage or outflow of hydrocarbon. These traps occur in form of structural, stratigraphic or a combination of both, structural traps can serve as barrier which prevent migration of the hydrocarbon, and includes rollover anticlines and flanks of salt domes (Coffen, 1984). Once an accumulation has been discovered, it is essential to characterize the reservoir as accurately as possible in order to estimate the reserves and to determine the most effective way of recovering as much of the petroleum as economically as possible (Selley and Sonnerberg, 2015). The principal goal of reservoir characterization is to obtain higher recoveries with fewer wells in better positions at minimum cost through optimization.

The first goal of reservoir characterization is to produce a geological model that can be used to predict the distribution of porosity, permeability and fluid throughout the field as well as describe the structural nature of the field (Slatt, 2006). Reservoir characterization leads to an incremental improvement in production of a field. The improvements come about because of better understanding of the geologic complexities and structure of the field. Various techniques such as gravity and magnetics methods of exploration geophysics have been employed by past and present geophysicists to study sedimentology, structural and accumulation of hydrocarbon in economic quantities. The knowledge of the structural geometry of a field or reservoir helps to delineate prospective locations good for accumulation of producible hydrocarbon in a field. Structural traps are formed as a result of changes in the structure of the subsurface due to processes like faulting and folding (Allen and Allen, 2005). The goal of structural interpretation is to assist in building possible reservoir description model and this involves the identification and description of structural and stratigraphic traps suitable for economic exploitation of hydrocarbon (Ameloko and Omali, 2013).

2. GEOLOGY OF THE STUDY AREA

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta province (Avbovbo, 1978). From the Eocene to present, the delta has prograded southwestward forming depobelts that represent the most active portion of the delta at each state of its development. These depobelts form one of the largest regressive deltas in the world with an area of about 300,000km^2, a sediment volume of about 500,000km^3 and a sediment thickness of over 10km in the basin depo-centre (Kulke, 1995; Hospers, 1965). The Niger Delta province contains only one identified petroleum system and this system is referred to as the Tertiary Niger Delta (Akata-Agbada) petroleum system as shown in Figure 1 (Ekweozor and Dakoru, 1994). Historically, the Niger Delta comprises of the following states Bayelsa, Delta and Rivers. But in the year 2000, the then government of Nigeria headed by Chief Olusegun Obasanjo included Abia, Akwa Ibom, Cross River, Edo, Imo and Ondo states in the region (CRS, 2008).

2.1 Akata Formation

This formation is traced back to Paleocene era, comprised of turbidite sands, small amount of silt, clay and thick shale. The thickness of the Akata formation is about 7,000 meters and it was formed during the lowstands in relative sea level (Tuttle et al., 2015). It is said to be part of the petroleum system found in the Niger Delta Basin, of Nigeria along the Gulf of Guinea, Atlantic Ocean (Wikipedia, 2021). According to the upper Akata

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Formation is said to be a primary source rock and house for Type II/III kerogen (Owoyemi, 2004). The clays are typically over-pressured due to lack of porous sediments during compaction (Wikipedia, 2021).

2.2 Agbada Formation

The Agbada Formation is of in Eocene age, it is marine facies having deep sea characteristics and is defined by fresh water (Wikipedia, 2021). This formation is the primary source of oil and gas in the basin. Its thickness is about 3,700 meters and the hydrocarbons present in it formed when the rocks became sub-aerial, covered in a marsh type environment rich in organic content.

2.3 Benin Formation

Benin Formation is youngest among the three that make up the basin and was formed from the Oligocene era. It is estimated to be about 2,000 meters thick, made up of plain sands and alluvial deposits. The formation is generally water bearing and is the main source of portable water in the Niger Delta (Wikipedia, 2021).

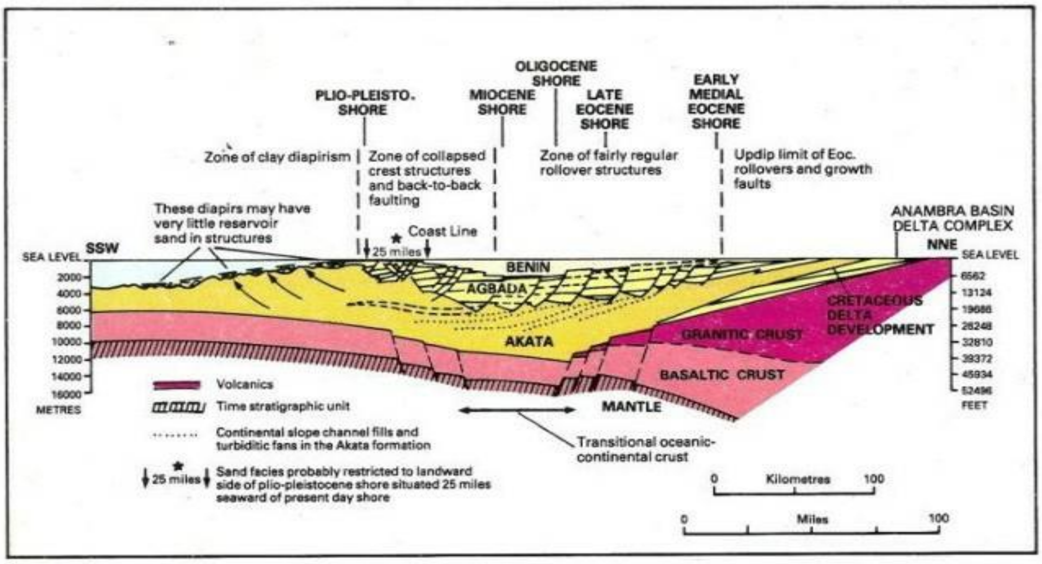

Figure 1: Geology of the Study Area (Short and Stauble, 1967)

3. Materials and Methods

3.1 Materials

The materials used for this study include:

- Base map
- Suite of well logs (comprising of gamma ray, resistivity, neutron and density logs)
- 3-D seismic sections (in-line and cross-line)
- Well check-shot
- Schlumberger Petrel software 2016 version.

3.2 Methodology

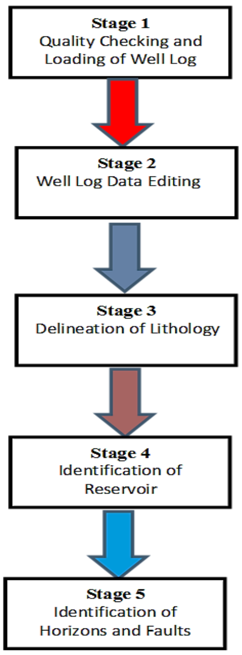

Figure 2: Five Stages of Method Used

This study is fundamentally on structural interpretation of Assa-field reservoir, the method adopted in this study is in five stages as shown in Figure 2.

3.2.1 *Loading of Well Log Data*

Well log data from Assa-field reservoir were checked for quality before being loaded into the petrel software. This is to ensure proper interpretation and to reduce interpretation difficulties.

3.2.2 *Well Log Data Editing*

The well log data were normalized and filtered to ensure the removal of abnormal datum or data which may have resulted from instrument reading or computational error.

3.2.3 *Delineation of Lithology*

Gamma ray log was used to delineate the lithology of the field into shale and sandstone beds or reservoirs. As the log reading tends towards the higher value, the field becomes more shaly whereas as the reading tends towards the lower value, the field becomes more sandy. The percentage volume of shale and sand in the reservoir were estimated using the following equations:

$$I_{GR} = \frac{GR_{log} - GR_{min}}{GR_{max} - GR_{min}} \quad (1)$$

$$V_{sh} = 0.33(2^{2I_{GR}} - 1.0) \quad (2)$$

$$\%Shale = V_{sh} \times 100\% \quad (3)$$

$$\%Sand = 100 - \%Shale \quad (4)$$

Where $I_{GR} = Gamma\ ray\ index$

$\%Shale$ = Percentage of shale by volume

$\%Sand$ = Percentage of sand by volume

GR_{log} = Formation Gamma ray log reading

GR_{min}= Gamma ray log reading in sand zone.

GR_{max}= Gamma ray log reading in shale zone.

3.2.4 Identification of Reservoir

Resistivity log was used to identify fluid type in the reservoir and thus differentiate between hydrocarbon and water bearing reservoirs. Hydrocarbon and gas reservoirs were identified as the log reads high resistivity values whereas water bearing reservoir was identified as the log show low resistivity values because of its high conductive nature.

3.2.5 Identification of Horizon and Faults

Structural interpretation involves visual inspection of seismic section to identify reflection discontinuities, vertical displacement of reflection events and abrupt distortion of events as well as changes which may occur in the pattern and strength of reflection events across the seismic section. Horizons (surface separating two different rock layers) were mapped or identified on the in-lines and cross-lines of the seismic section by manual picking and used to generate time structure maps which were converted to depth structure maps using check-shot. Identification of faults from the seismic section was done by distinct discontinuity or abrupt jump of seismic reflection events (on the basis of discontinuities in reflection events).

4. Results and Discussion

4.1 Results

The results of the detailed study on the structural interpretation of Assa-field reservoir in Niger Delta is presented in the following sub-headings:

4.1.1 Structural Framework

This involves fault modeling, horizon making and gridding (pillar gridding). Fault modeling entails defining the different faults identified, which formed the foundation for generating the 3-D grid.

4.1.2 Structural Modeling

Structural modeling was carried out using the 3-D seismic section. Horizon and fault were identified and interpreted from the seismic sections. Time contour and depth structure maps were also produced from the seismic sections as shown in Figures 3 and 4 which shows 3-D cross section (cross-line 1297) with an unpicked and picked horizons respectively.

4.2 Discussion

4.2.1 Horizon Interpretation

Identification, mapping, interpretation of horizons were carried out and correlated across the fields. Picking of horizon was carried out iteratively and examined for misties. At some points in the field where the quality and characteristics of reflection are good, quality lines were picked at greater intervals whereas at the quality of reflection is poor, lines were picked at closer intervals so as to minimize miss-ties to the acceptable range as shown in Figure 4. Three primary horizons were mapped and interpreted on the basis of uniqueness and features; they are sand A, sand B and sand C.

4.2.2 Fault Interpretation

Seismic section reveals the appearance of patterned reflection discontinuities for proper identification and interpretation. Apart from the major faults identified, there is the existence of other small faults formed due to post depositional process and are most times referred to as synthetic secondary faults. The visibility of these faults in this field shows accumulation of hydrocarbon is possible because Welber and Dankoru described faults as good pathway for the migration hydrocarbon into the reservoir rocks (Welber and Dankoru, 1975).

4.2.3 Depth Structure Map

From the horizon and fault interpretation, depth structure map was generated, structural highs are stretched over the field and are colored with purple whereas structural lows are the yellowish/goldish colored areas.

4.2.4 Time Structure Map

Data interpretation was made possible with the generation of time structure map. It gives the data interpreter a 3D perspective of the mapped surfaces. Identified and mapped horizons and the generated faults were used to generate the time structural map for the three horizons. The corresponding time values of the horizons on all the cross-lines were picked with the use of the in-line to generate the time map.

4.2.5 Lithology and Reservoir Identification

Two main lithologies present in the field as identified by the gamma ray log are sand and shale. The interval coloured yellow denotes sand while the interval coloured black signifies shale as shown in Figure 5.

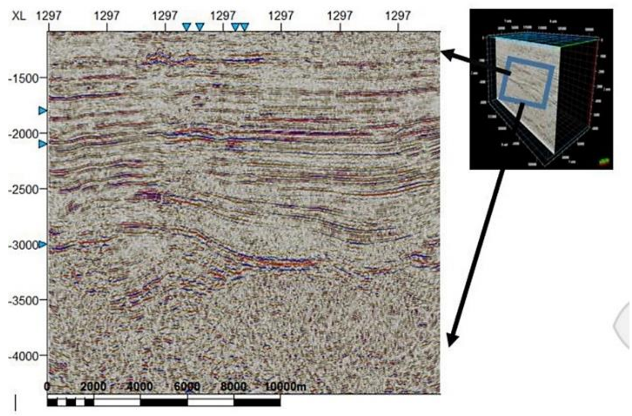

Figure 3: Crossline 1297 Showing 3-D Cross Section with Uninterpreted Horizon

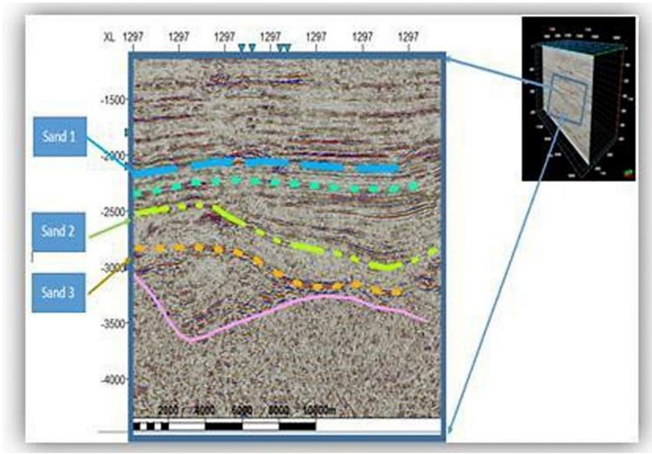

Figure 4: Cross-line 1297 Showing 3-D Cross Section with Interpreted Horizons

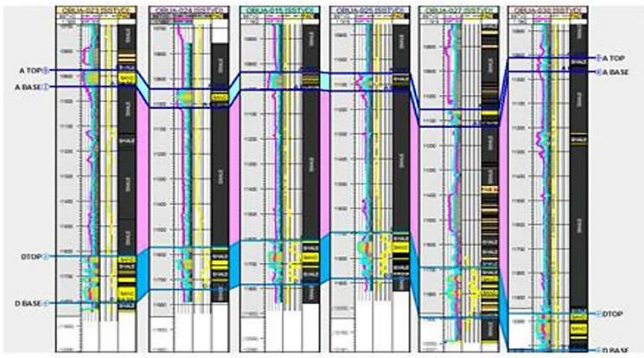

Figure 5: X-Field Wells Correlation Panel

5. Conclusion

Structural interpretation was effectively carried out for mapping of structures, characterize and investigate the hydrocarbon trapping potential of Assa-field reservoir in Niger Delta using well log.

From the results of this study, the following conclusions are reached.

1) The trapping pattern in the field favored for hydrocarbon accumulation on the basis of anticlinal structure inherent in the field.

2) The most inclined fault defines the largest closure which is the prospect zone.

3) The northern part of the field forms a large closure against the fault.

4) The visibility of faults in the field shows that the accumulation of hydrocarbon is possible.

5) The three primary horizons mapped are on the basis of uniqueness, clarity and features.

6) The time and structure maps show more details of the structure of the field.

7) Major faults were delineated on the 3-D seismic section and minor faults were formed by post depositional process.

Sand and shale are the two key lithological units existing in the field.

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