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# Structural interpretation of seismic data from an xy field, onshore Niger Delta, Nigeria.

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**ABSTRACT:** In this study, the hydrocarbon potential of XY-field in (onshore) Niger Delta was evaluated using seismic, well logs and check shot data. Two horizons were identified at 2120ms (horizon A) and 2250ms (horizon B).Two types of faults were identified, which are the synthetic and the antithetic faults. The identified synthetic faults, trending in the Northeast- Southeast direction are; F1, F2, F3, F4, F5, F6 and F7, respectively while the antithetic faults which trend in the Northwest-Southeast direction are A1, A2, A3 and A4, respectively. Two reservoirs were delineated at depth range of 7,000-7,150ft and 8,000-8,120ft. The principal structure responsible for hydrocarbon entrapment in the field is a structural high which probably correspond to the crest of the rollover structure observed on the seismic sections. This was observed as fault assisted closures on the depth structural map of the horizons. The antithetic and growth faults act as good traps for the hydrocarbon accumulation in the study area. © JASEM

The Niger Delta is ranked among the major prolific deltaic hydrocarbon provinces in the world and is the most significant in the West African continental margin. Oil and gas in the Niger Delta are principally produced from sandstones and unconsolidated sands predominantly in the Agbada formation. Several geological and geophysical investigations have been performed in the Niger Delta basin starting about fifty years ago for oil and gas prospecting ( Aizebeokhai and Olayinka, 2011; Cobbold et al., 2009).

Several workers have carried out structural analysis in different sedimentary basins worldwide using seismic and well log data. Similarly, the structural interpretation of the seismic data, petrology and depositional environment of the reservoir sandstones from different part of the Niger Delta have been carried out to determine the hydrocarbon potentials of the area by various researchers (Hamed and Kurt, 2008; Wiener et al.,1997; Haack *et al*. 2000; Hooper *et al*. 2002; Ajakaiye & Bally 2002*a*, *b*; Morgan 2003).

Subsurface configurations must be understood in detail to effectively delineate the structures that are favourable for hydrocarbon accumulation. This is because hydrocarbons are found in geological traps. These traps may be structural or stratigraphic (Coffee, 1984). According to Doust and Omatsola (1990), majority of traps in the Niger delta are structural, therefore this work will focus on the mapping of the structural features available in the study area.

The aim of this work is to review the application of seismic survey to imaging subsurface structures and to indicate favourable areas in which exploration can be concentrated especially at deeper levels. This will involve tracing of seismic horizons, identification of structural traps and then posting them on the base map to form the time horizon maps which was further converted to depth structural map.

*Geology of Niger Delta:* The study area is located within the northern depobelt of the Niger delta sedimentary basin (Fig. 1). The Niger-Delta forms one of the world's major Hydrocarbon provinces and it is situated on the Gulf of Guinea on the west coast of Africa (Southern part of Nigeria). It covers an area between longitude 4 – 9°E and Latitude 4 - 9° N. It is composed of an overall regressive clastic sequence, which reaches a maximum thickness of about 12km (Evamy et al.; 1978).

The Niger Delta was formed as a result of the African and South American plate, at the site of the triple junction in the late Jurassic and continuing into the cretaceous, thus leading to the opening of the Southern Atlantic. The Niger Delta is a low gradient delta plain-shelf slope wedge with an estimated area exceeding over 200,000 square kilometres. The tectonic framework of the continental margin along the west coast of Equatorial Africa is controlled by Cretaceous fractured zones expressed as trenches and ridges in the deep Atlantic. The trough represents a failed rift triple junction associated with the South Atlantic. After the rifting ceased, gravity tectonism became the primary deformational process.

During the Cretaceous, the area presently occupied by the Niger Delta was the site of a RRR (ridge-ridge-ridge) triple junction. The evolution of the Niger delta is related to the development of the RRR triple junction and the subsequent separation of the South American and African continents (Kulke, 1995),

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The Niger delta has built out over the collapsed continental margin at the site of the triple junction formed during the Middle Cretaceous. The main sediment supply has been provided by an extensive drainage system, which in its lower ridges follow two failed rift arms, the Benue and Bida basins, (Burke et al, 1971). Sediment input generally has been continuous since the Late Cretaceous, but the regressive record has been interrupted by episodic transgressions. The bulk of the sediment was from the north and east during most of the Tertiary, even though there is little evidence for substantial Tertiary uplift in much of the catchment areas of the Niger–Benue river systems. According to Evamy et al (1978) the development of the Tertiary Niger Delta can be seen as a function of the rate of sedimentation (Rd) and rate of subsidence (RS). When the rate of sedimentation (Rd) is greater than the rate of subsidence (RS), the delta progrades, when the rate of sedimentation (Rd) is equal to the rate of subsidence (RS), the Delta remains stationary, when the rate of sedimentation (Rd) is less than the rate of subsidence (RS), the Delta retreats. The variations in the relations of Rd and Rs result in the development of distinct sedimentary mega-units of different shapes, extent and thicknesses.

Three lithostratigraphic units are distinguished in the Tertiary Niger Delta. The basal Akata Formation which is predominantly marine prodelta shale is overlain by the paralic sand/shale sequence of the Agbada Formation. The topmost section is the continental upper deltaic plain sands – the Benin Formation. Virtually all the hydrocarbon accumulations in the Niger Delta occur in the sands and sandstones of Agbada Formation where they are trapped by rollover anticlines related to growth fault development (Doust and Omatsola, 1989; Morgan 2003).

## MATERIAL AND METHODS

The data used in the study include wireline logs, checkshot data, 3-d seismic sections and base map of the study area; all of which were imported into the interactive workstation. The base map of the seismic survey is shown in Figure 2. The seismic lines are cross-lines shot parallel to the dip direction and inlines which were shot parallel to the strike direction. The wireline logs consist of gamma ray and resistivity logs for two wells X and Y. The interpretation was carried out using openworks (seisworks) software.

The gamma ray and resistivity logs were used in identifying the lithologies penetrated by the wells. The resistivity log was also used in distinguishing between saline-bearing water formations and hydrocarbon pay zones. The available wireline log signatures were employed in identifying hydrocarbon- bearing reservoirs. The lithofacies interpreted from well logs were matched against reflection events from seismic sections. The selection of reflection events from the seismic sections was based mainly on amplitude and continuity of such reflections, especially in areas where there were no well control. The checkshot data for well X was used for the well-to-seismic tie of the hydrocarbon reservoirs. This tie formed the first step in picking events, which corresponded to the tops of the sands for interpretation. Lithofacies (horizons) within the well logs that show hydrocarbon prospect were selected for mapping. The depths of these horizon were converted to two-way travel times using the time-depth relation curve (Fig. 3). The corresponding seismic reflection events that show

reasonable amplitude and continuity were selected. The identified horizons were tracked on the reflections, on both the inlines and crosslines across the field to produce the time structure (isochron) maps. Major faults were identified base mainly on break in reflection events or abrupt termination of reflection events and marked on the cross-lines. Consistency of the fault traces at all levels was ensured. Depth structure maps were produced from the time structure maps using the velocity information derived from checkshot data.

## RESULTS AND DISCUSSION

The seismic volume presented here extends to 3.5 seconds two way travel time below which seismic amplitudes are very low and reflections are very chaotic. They constitute low reflectivity package, lacking laterally continuous internal reflections. The character of the seismic record changes with depth. The structural interpretation of the seismic data is presented in figures 4 and 5. Based on the well to seismic ties two horizons were identified in the seismic sections. These two horizons were named horizon A and B. The two horizons in the inline seismic section occurred at the levels of 2120ms (horizon A) and 2250ms (horizon B). The horizons were picked in the crossline by following the intersections of the inline and cross line sections.

The fault analysis was carried out on the inline section because this gives a clearer picture of the fault pattern in area. This is as a result of the trending pattern of the fault which is East-West and the inline is running North-South. Thus, the inline is perpendicular to the faults in this area. Two types of faults were identified, which are the synthetic and the antithetic faults. The identified synthetic faults, trending in the Northeast- Southeast direction are; F1, F2, F3, F4, F5, and F6 while the antithetic faults which trend in the Northwest-Southeast direction are A1, A2, A3 and A4. The major faults become less apparent as the seismic record becomes obscured by larger transparent zones at depths. Down-dropped blocks of major faults are deformed into broad anticlines. The antithetic faults radiate from the crest of the anticlines.

Lateral transition from transparent seismic zones to more continuous reflection in the basal parts of seismic record occur as shallow levels under footwall blocks adjacent to major faults relative to under hanging blocks. These low amplitude discontinuous to transparent reflection zones having variable to abrupt or diffuse-gradational boundaries are interpreted to reflect deposits that have been fractured by overpressures and perhaps have moved upward under the weight of overlying strata during fault displacement. The occurrence of these transparent seismic patterns at shallow depths just landward of major faults may reflect isostatic rebound of footwall blocks as down-dropped blocks detached and shifted basinward.

The horizon A and B depth structural maps generated from the time structural maps with the aid of the velocity obtained from the checkshot data are shown in Figure 6 and Figure 7 respectively. Analysis of the depth structural map shows that around the two wells (XY-1) and (XY-2), the contours have perfect closure which is on a high implying the existence of reservoirs whose crests occur at 7,000ft and 8,000ft. The digitized areas in yellow colour show the extent of hydrocarbon accumulation in the closures. Six prospects were also identified at various structural highs. These are prospects P1, P2, P3, B1, B2 and B3. The principal structure responsible for hydrocarbon entrapment in the field is a structural high which probably correspond to the crest of the rollover structure observed on the seismic sections. This was observed as fault assisted closures on the time and depth structural map of each horizon. The antithetic and synthetic faults act as good traps for the hydrocarbon accumulation in the study area.

*Conclusion:* In this study, the hydrocarbon bearing reservoir intervals of the X field in the Niger delta has been delineated and map from surface seismic and well logs data. Two horizons A and B were identified at the time levels of 2120ms and 2250ms on the seismic section. The depth equivalents of the two horizons are 7000ft and 800ft respectively. The structural analysis showed that there are six synthetic (F1 through F6) and four antithetic (A1 through A4) faults in the area. The faults are responsible for hydrocarbon entrapment in the field. Hydrocarbon prospect areas were delineated in the depth structured maps produced. Finally, the information obtained from the seismic interpretation has resulted in more understanding of the structures and hydrocarbon potentials of the Northern Niger Delta depobelt.

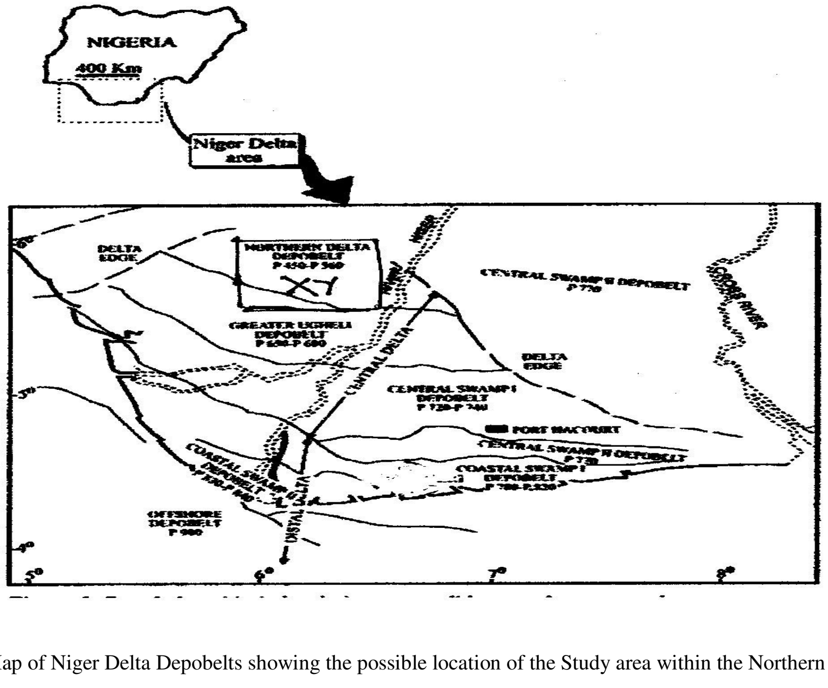


**Fig.1**: Map of Niger Delta Depobelts showing the possible location of the Study area within the Northern depobelt.

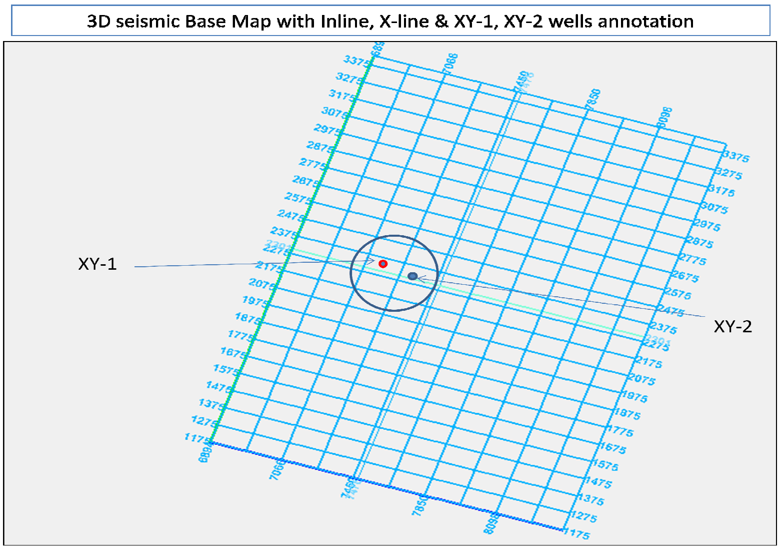


**Fig: 2:** Base map of the study area showing well locations and seismic lines

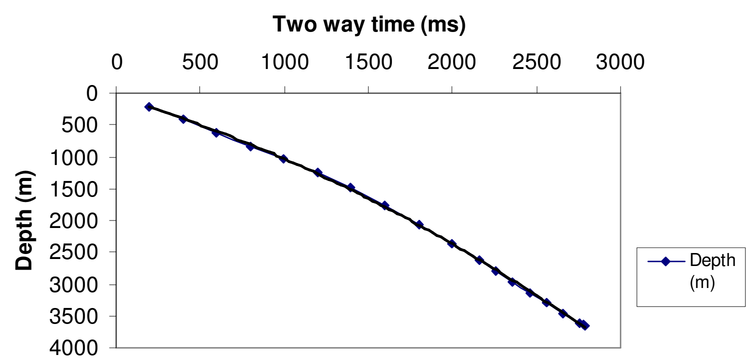


**Fig. 3:Checkshot Plots used to Generate Depth Horizons**

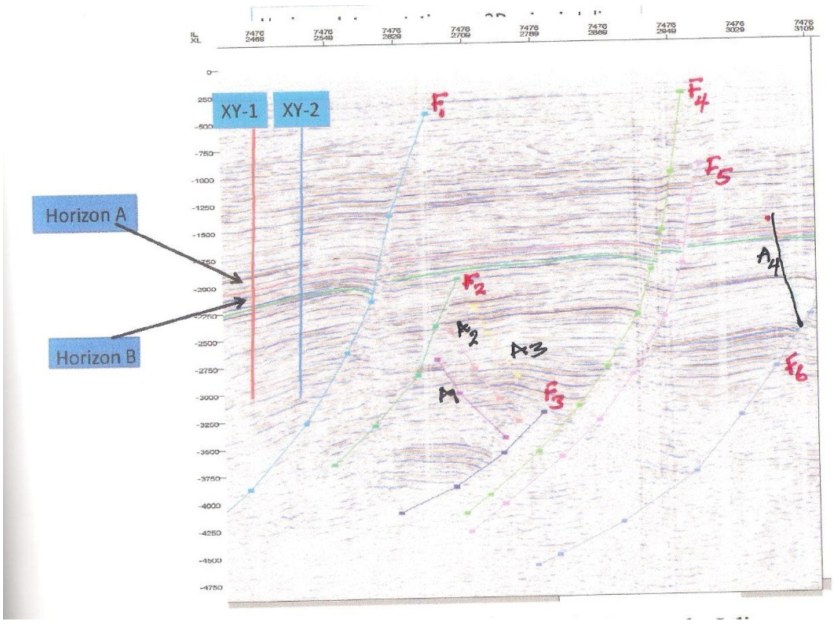


**Fig 4**: Picked faults, seismic horizons and wells on inline

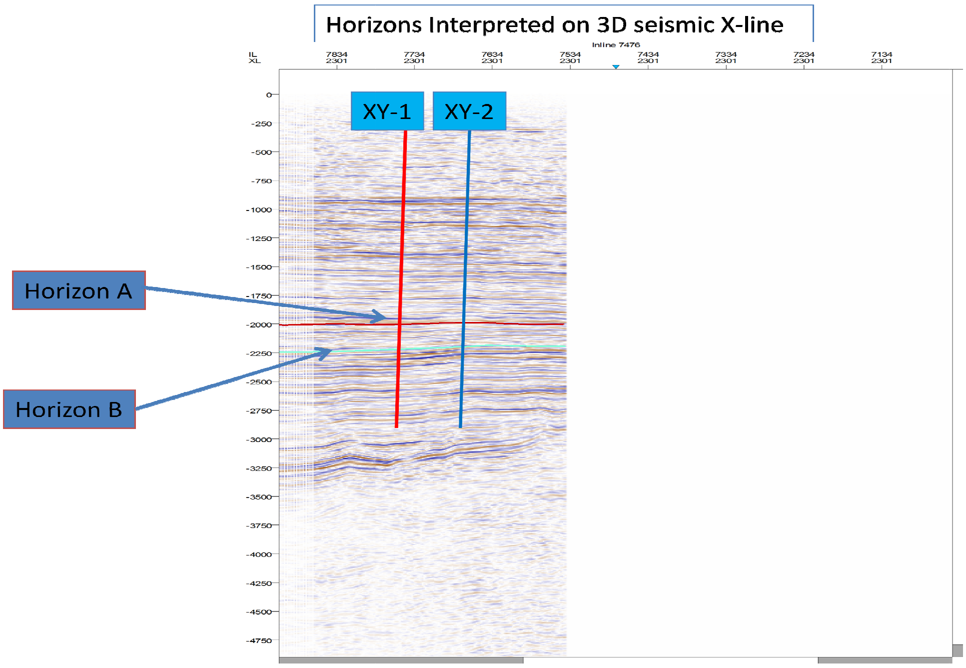


**Fig. 5**: Horizons interpretation on the cross line seismic section

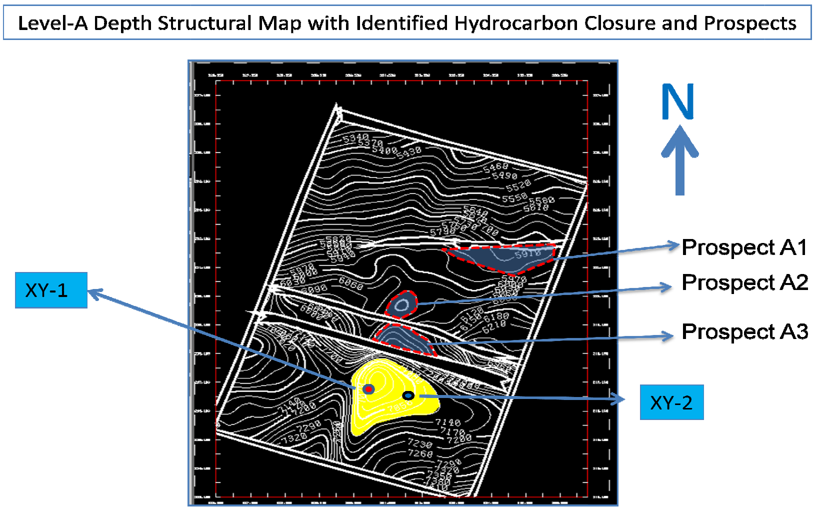


**Fig. 6**: Depth structural map with identified hydrocarbon closure and prospects for horizon A

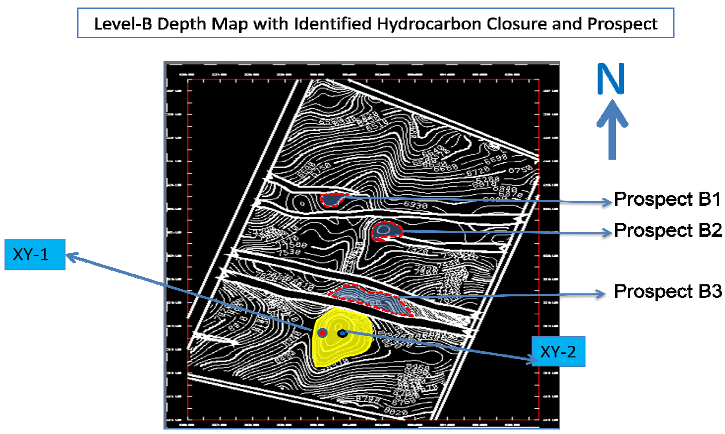


**Fig. 7**: Depth structural map with identified hydrocarbon closure and prospects for horizon B

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