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Research paper

Hydrocarbon prospectively determination of "eagle field", coastal swamp ii Niger delta.

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Abstract

Seismic and well log data were collected from onshore depobelt of Nigeria with a total of 1000 seismic lines and 3 wells. The main objective of the study was to determine hydrocarbon prospectivity and reserve estimates of the field. The evaluation centred on seismic interpretation and 3D visualisation (DHI detection) of the "Ejanla Field" 3D in total, Four horizons have been interpreted regionally for correlation purposes and three as prospect specific horizons. Four prospects and some, more speculative leads were identified in the area of which most are conventional three way dip/fault closures and some hanging wall closures. The potential for stratigraphic trapping was also recognized. The study showed that the small closure areas and limited hydrocarbon column lengths affected the number of prospects and at the shallow levels.The main risk to oil prospectivity in the area as revelled by the data interpretation is gas which may have resulted from the observed higher geothermal gradient in the deeper depth. Reservoir development and retention (overpressure) for prospects and leads in the deeper and more distal sedimentological settings form additional risks.

Keywords: *Prospectively; Deponents; Prospect; Reservoir; Net-To-Gross; Porosity;Gross Thickness and Hydrocarbon Exploration.*

1. Introduction

The purpose of the study was to establish a thorough understanding of the major structural elements within the Ejanla Field of Niger Delta and identify prospective areas for hydrocarbon exploration.

1.1. Location/ description of the study area

Ejanla Field is located in offshore Niger Delta approximately within 45ft water depth (Figure1) Faulted Rollover Anticline situated down thrown of two major NW-SE linked listric normal fault systems. There are Six major fault blocks identified. Trapping mechanism is largely structural, but there are stratigraphic controls on fluid flow (production).

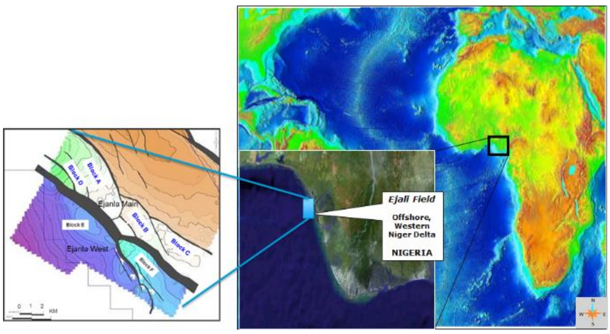

Fig. 1: Location Map of Ejanla Field.

2. Geology of the study area

The Niger delta is located on the continental margin of the Gulf of Guinea (between latitude 30 and 60N and longitude 50 and 80E) and represents the southern margin of the triple junction rift system that triggered the separation of the African continent from the South American continent during the Jurassic through the Early Cretaceous. It is one of the most prominent hydrocarbon provinces ranking among the world's first twenty largest producing nations (National Oil Companies, 2009). It is also the most prolific sedimentary basin in West Africa and the largest in Africa (Reijers, 1996;Reijers et al, 1997) from the economic and commercial point of view as it covers a land area in excess of 105,000 km2 (Avbovbo, 1978) and its petroleum reserves provide the largest portion of the country's foreign exchange earnings.

The geology, stratigraphy and structure of the Niger delta basin have been extensively discussed in several key publications (Short and Stauble, 1967; Merki, 1971; Avbovbo, 1978;Evamy et al, 1978; Burke and Whiteman, 1970.) with the source rock for hydrocarbon in the Niger Delta being a subject of discussion (e.g. Evamy et al, 1978; Ekweozor et al, 1979; Ekweozor and Okoye, 1980; Lambert-Aikhionbare and Ibe, 1984; Ejedawe, 1981; Doust and Omatsola, 1990), Tuttle, Charpentier and Brownsfields (1999) and Ajakaiye and Bally (2002). There are five offlapping siliciclastic sedimentation cycles postulated and recognized as being responsible for the deposition of the three subsurface Niger Delta formations; Benin, Agbada and Akata. These cycles known as depobelts namely; the Northern, Greater Ughelli, Coastal Swamp, Central Swamp and Offshore have widths of upwards of 30-60 kilometres and prograde 250 km southwestwardly over the oceanic crust into the Gulf of Guinea. Each depobelt recognized in the Niger-Delta has its own sedimentation, deformation, and petroleum generation history

2.1. Tectonics

The tectonic framework of the Niger Delta is related to the stresses that accompanied the separation of African and South American plates, which led to the opening of the South Atlantic. Evolution of the Niger Delta is controlled by pre and syn-sedimentary extensional tectonics (Evamy et al., 1978). Ejedawe (1981) also corroborated this fact.

Pre-sedimentary tectonics in this basin is related to its basement rock architecture. This framework of the Niger Delta is controlled by deep seated Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic (Fig. 1). This fracture zone ridges which extend along most of the equatorial Africa, subdivided the margin into individual basins. In Nigeria, it forms the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield (Tuttle, Charpentier and Brownsfields, 1999). Other fractures along the West African coast include the Romanche, Chain and Charcot Fault zones.

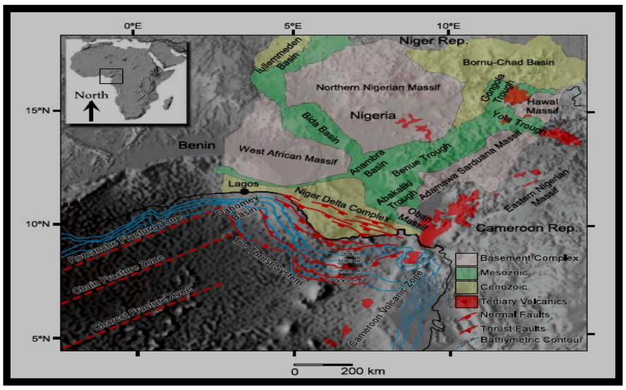

Fig. 2: Location Map of the Niger Delta Region Showing the Main Sedimentary Basins and Tectonic Features.

2.2. Stratigraphic setting

The stratigraphy of Niger Delta is complicated by the syn-depositional collapse of the clastic wedge as shale of the Akata Formation mobilized under the load of prograding deltaic (Agbada) and fluvial (Benin) Formation deposits. Three major depositional cycles have been identified within Niger Delta (Short and Stauble, 1967; Doust and Omatsola, 1990). The first two, involving mainly marine deposition, began with a middle Cretaceous marine incursion and ended in a major Paleocene marine transgression. The second of these two cycles, starting in late Paleocene to Eocene time, reflects the progradation of a "true" delta, with an arcuate, wave- and tide-dominated coastline. These sediments range in age from Eocene in the north to Quaternary in the south (Doust and Omatsola, 1990). Deposits of the last depositional cycle have been divided into a series of six depobelts (Doust and Omatsola, 1990) also called depocentres or megasequences, separated by major syn-sedimentary fault zones (Fig. 2).These cycles (depobelts) are 30-60 kilometres wide, prograde 250 kilometres southwestwardly over oceanic crust into the Gulf of Guinea (Stacher, 1995), and are defined by syn-sedimentary faulting that occurred in response to Variable rates of subsidence and sediment supply (Doust and Omatsola, 1990). A depobelt therefore, forms the structurally and depositionally most active portion of the delta at each stage of its development.

The Niger Delta Basin evolved in a protracted style where subsidence and sedimentation within a depobelt may have been facilitated by large scale withdrawal and seaward movement of undercompacted and geopressured marine shales under the weight of advancing parralic clastic wedge (Doust and Omatsola, 1990). At a certain stage however, further subsidence and sedimentation could no longer be accommodated and the focus of deposition shifted basinward to form a new depobelt. Similarly, syn-sedimentary and most post-sedimentary faulting ceased with the abandoned depobelt. Normal faults triggered by the movement of deep-seated, overpressured, ductile, marine shale have deformed much of the Niger Delta clastic wedge. Growth faults affecting the sequence within depobelts form the boundaries of macrostructures (or individual delta units), each with its own sand shale distribution pattern and style. Depobelts or mega-structures comprise in fact families of genetically and temporally related growth fault trends, or macrostructures (Doust and Omatsola, 1989).

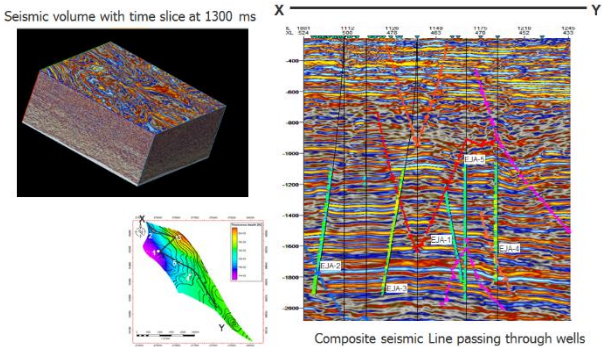

Fig. 3: Seismic Data Used in the Study.

2.3. Regional stratigraphy

The Niger Delta basin consists of Cretaceous to Holocene marine clastic strata that overlie oceanic and fragments of continental crust (Figure 4). The Cretaceous section has not been penetrated beneath the Niger Delta basin, and thus, Cretaceous lithologies can only be extrapolated from the exposed sections in the next basin to the northeast, the Anambra basin (Figure 3). In this basin, Cretaceous marine clastics consist mainly of Albian–Maastrichtian shallow-marine clastic deposits (Nwachukwu, 1972; Reijers et al., 1997). The precise distribution and nature of correlative Cretaceous deposits beneath the offshore Niger Delta is unknown. From the Campanian to the Paleocene, both tide dominated and river-dominated deltaic sediments were deposited during transgressive and regressive cycles, respectively (Reijers et al., 1997). In the Paleocene, a major transgression, referred to as the Sokoto (Reijers et al., 1997), initiated deposition of the Imo shale in the Anambra basin and the Akata shale in the Niger Delta basin. During the Eocene, the sedimentation changed to being wave dominated (Reijers et al., 1997). At this time, deposition of parralic sediments began in the Niger Delta basin, and as the sediments prograded south, the coastline became progressively more convex seaward. Today, delta sedimentation remains wave dominated (Burke, 1972; Doust and Omatsola, 1990).

Short and Stauble (1967) subdivided the Niger delta into three lithostratigraphic units, ranging in age from Paleocene to Recent. The formations are coeval (Figure 4). The base of the formation consists of thick sequences of massive prodelta, hemipelagic, and pelagic shales deposited in marine environments (Akata Formation). The Akata Formation contains a few streaks of turbidite sands deposited in holomarine environments. This Formation is of marine origin and is of late Paleocene to early Pliocene in age. The Akata is characterized by high plasticity and overpressure, especially at depth. All major faults and counter-regional faults merge into a plane (or detachment surface) in the lower part of the Akata Formation. Though little of the Akata Formation has been drilled, it is estimated that the formation could be up to 23,000 ft (7,000 m) thick (Doust et al., 1990; Tuttle et al., 1999). This Formation grades upwards into interbedded shallow marine and fluvial sands, silts and clays which form parralic facies portion of the delta (Agbada Formation). The uppermost part of the sequence is a massive non-marine sand section called the Benin Formation.

The Agbada Formation consists of a parralic sequence of interbedded sandstones and shales and forms the hydrocarbon prospective sequence in the Niger Delta. This parralic sequence is truly the Deltaic portion of the sequence and were deposited in delta-front and fluvio-deltaic environments. The sandstones were deposited in Prograding transitional or coastal environments comprised of the fluvio-deltaic and barrier islands of the delta front, lagoon, brackish-water bays, beaches, and the shoreface. Shales are prodelta to hemipelagic in origin. The Agbada Formation is Eocene to Pleistocene in age and about 9,900 ft (3,300 m) thick. The Benin Formation consists of continental sandstones that were deposited in the delta plain as point bars by meandering streams or as channel fills with natural levees (Doust et al., 1990). The massive fresh-water bearing Benin Formation occurs widely across the Niger delta, with thicknesses ranging between 1,000 and 10,000 ft (300 and 3,000 m). The Benin Formation does not play a significant role in the evolution of the Niger delta petroleum system, except as overburden.

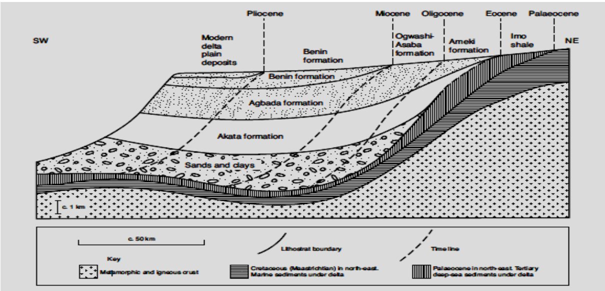

Fig. 4: Lithostratigraphic Description of the Niger Delta Basin Showing the Stratigraphic Equivalences between the Outcropping and the Subsurface Niger Delta (after Wright Et Al., 1985).

2.4. Local stratigraphy

The "Ejanla" reservoirs have been previously interpreted in regional context as predominantly shoreface deposits within the wave-dominated Niger Delta and were documented to have been deposited during the Middle to late Miocene (Figure 2). The reservoir sandstones were predominantly deposited in a wave dominated environment within the shoreface of the Niger delta (Powers, 1996; Ewins, 1997). The Opuama Channel complex, which was initiated during the late Oligocene drop in sea level and active through the Middle Miocene, made incisions into several western Niger Delta hydrocarbon fields, including "Ejanla Field".

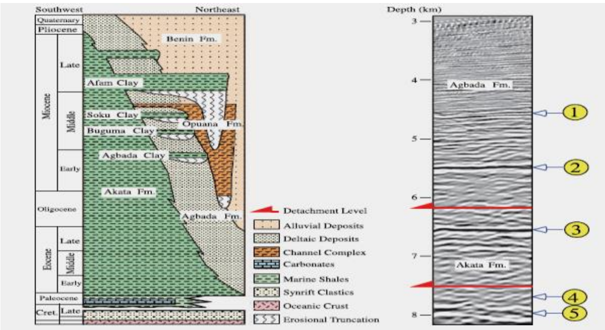

Fig. 5: Schematic Diagram of the Regional Stratigraphy of the Niger Delta (Showing the Three Formations of the Niger Delta) and Variable Density Seismic Display of the Main Stratigraphic Units in the Outer Fold and Thrust Belt and Main Reflectors, Including (1) Top of the Agbada Formation, (2) Top of the Akata Formation, (3) Mid-Akata Reflection, (4) Speculated Top of the Synrift Clastic Deposits, and (5) Top of the Oceanic Crust. Main Detachment Levels Are Highlighted With Red Arrows. Stratigraphic Section is modified from Lawrence Et Al. (2002).

3. Material and method of data analysis

Well-log and seismic correlations were used to construct a regional chronostratigraphic framework. Seismic-to-well ties were based on checkshot surveys, sonic logs, and vertical seismic profile (VSP) data available for this project.

Structure Faults were first mapped on the basis of seismic expression and confirmed from available well logs. The correlation of fault traces was completed with a high degree of certainty where intersecting seismic lines showed intersecting fault traces. The correlation of faults was difficult between widely spaced seismic lines. In such cases, fault correlations were also based on fault shape and patterns of dip panels found on both upthrown and downthrown sides of the fault.

4. Results and discussion

This correlation panel showed the tops of the reservoirs across the five wells. This correlation panel showed the top and base of the selected and mapped hydrocarbon bearing reservoirs across the five wells (Fig. 7 and 8). While the E15 and E21 reservoirs were correlated across the five wells.

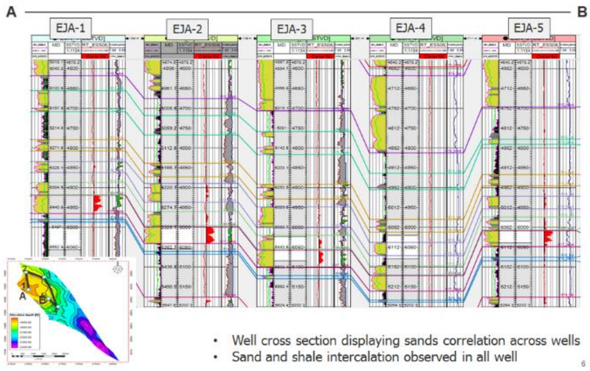

Fig. 7: Well Correlation Panel through Eja -1, -2, To Eja-5.

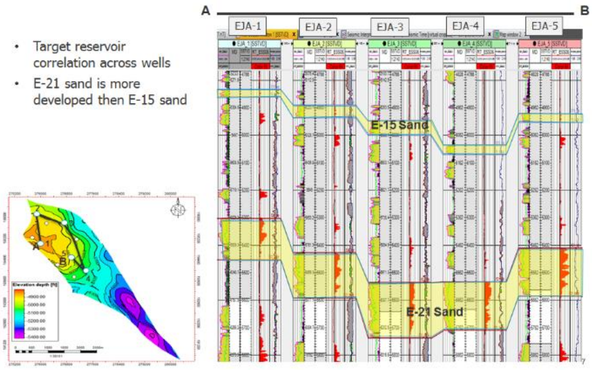

Fig. 8: Structural Cross Section through Target Sands.

Synthetic seismograms were utilized for the seismic-to-well ties. They revealed a high amplitude reflection events corresponding to sand units, whereas, low amplitude reflection events correspond to shale units.

The seismic to well tie was done for Eja-1 which is the only one having both sonic and density logs since these are the logs used to generate acoustic impedance (velocity X density) and eventually the Reflection coefficient (Fig. 9). The purpose of Seismic to well tie was basically to make sure that the reservoir picked on the well logs is the one interpreted on the seismic volume.

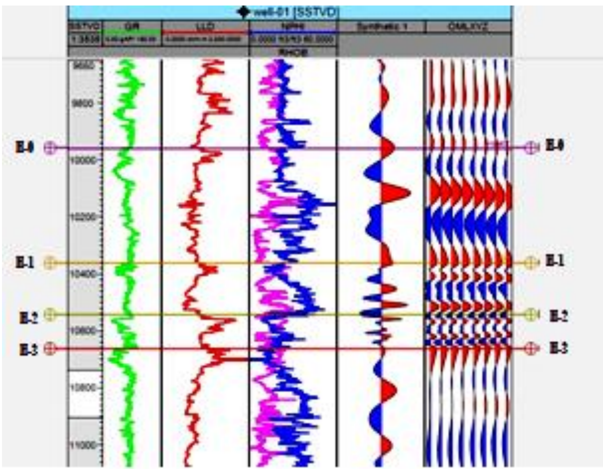

Fig. 9: Seismic to Well Tie Showing A Relatively Good Well to Seismic Tie.

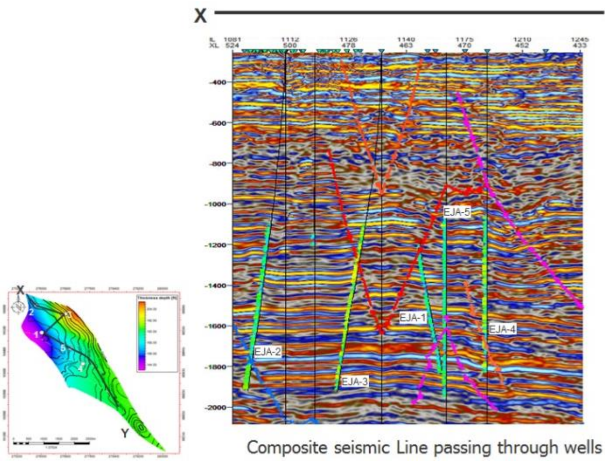

Fig. 10: Interpreted Seismic Line in Study Area.

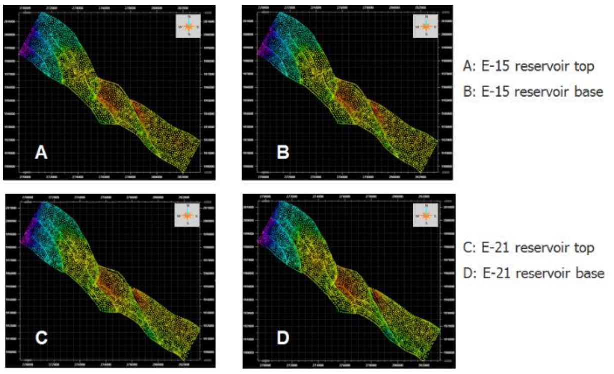

Fig. 11: Time Structure Map of the Horizons.

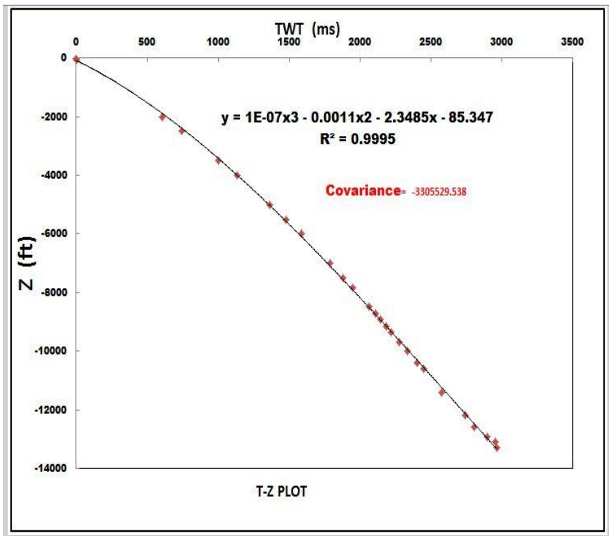

Fig. 12: Time-Depth Plot Used in the Time-Depth Conversion.

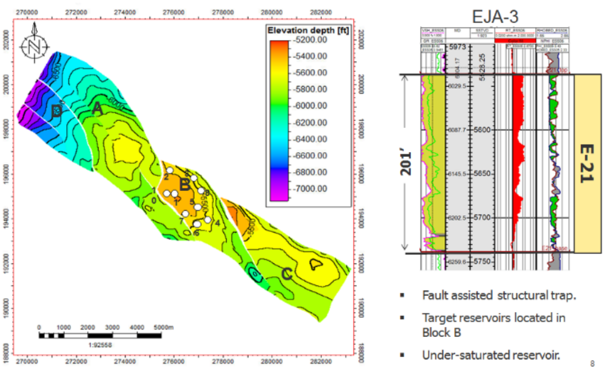

Fig. 13: Depth Strucuure Map of Reservoir E-21.

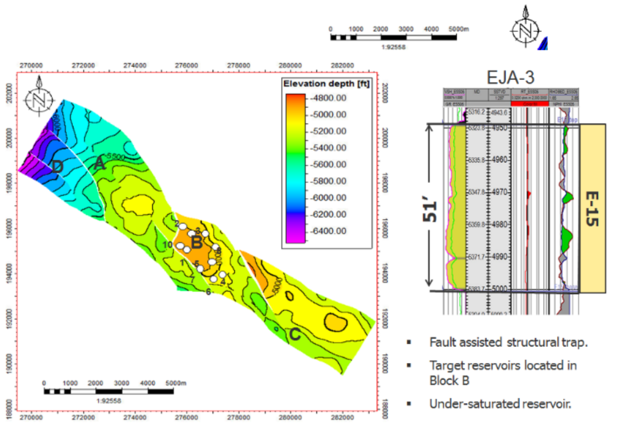

Fig. 14: Depth Strucuure Map of Reservoir E-15.

Reservoir Property

For E-21 Reservoir, gross thickness, NTG and porosity increase in the North-east direction. Gross thickness, net-to-gross thickness and porosity range between 138ft and 212ft, between 0.71 and 1.0, between 0.268 and 0.326 respectively (Figure15). Sand quality decreases towards the North-west. Figure 16 shows the E-21 Reservoir Original Structural Cross Section. Original Oil Water Contact in EJA-3 is at -5723ft tvdss. There is no gas indication in the crestal parts of the wells. E-21 sand quality diminishes towards the structural high in EJA-1.

For E-15 Reservoir, gross thickness, NTG and porosity increase in the North-east direction. Gross thickness, net-to-gross thickness and porosity range between 23ft and 57ft, between 0.714 and 1.0, between 0.278 and 0.328 respectively (Figure17). Sand quality decreases towards the North-west. Original Oil Water Contact in EJA-3 is at 4989ft. E-15 is a low resistivity sand and its quality diminishes towards the structural flanks in EJA-1 and EJA-2.

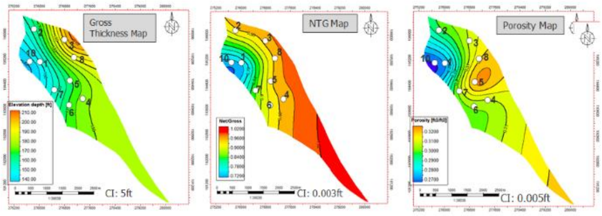

Fig. 15: E-21 Reservoir Property Maps.

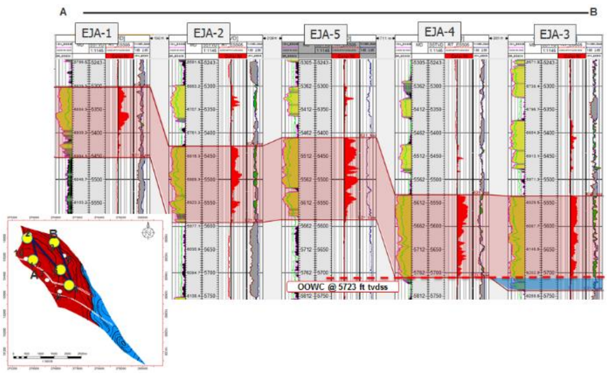

Fig. 16: E-21 Reservoir Original Structural Cross Section.

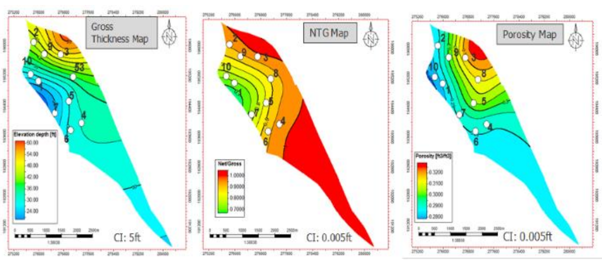

Fig. 17: E-15 Reservoir Property Maps.

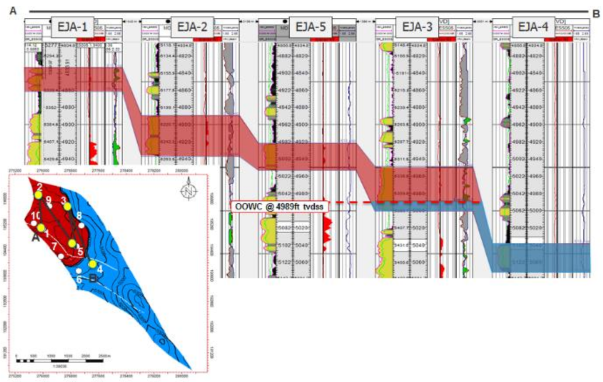

Fig. 18: E-15 Reservoir Original Structural Cross Section.

Reservoir Stratigraphy

Sand generally thickens towards the East direction. Reservoir quality gets better in same direction while gross sand package range from 150ft – 201ft both reservoirs as shown in Figure 19 and 20. Bulky sand packages are evident in E-15 reservoir.

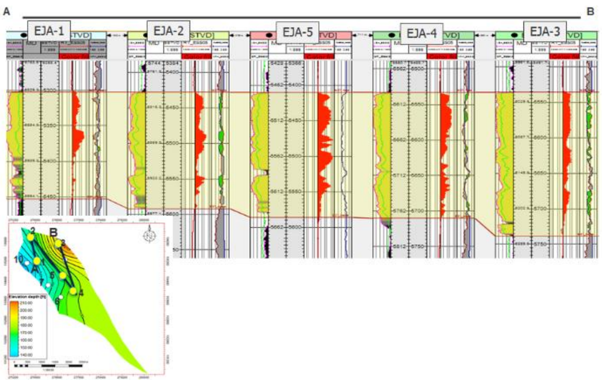

Fig. 19: E-21 Reservoir Stratigraphic Cross Section.

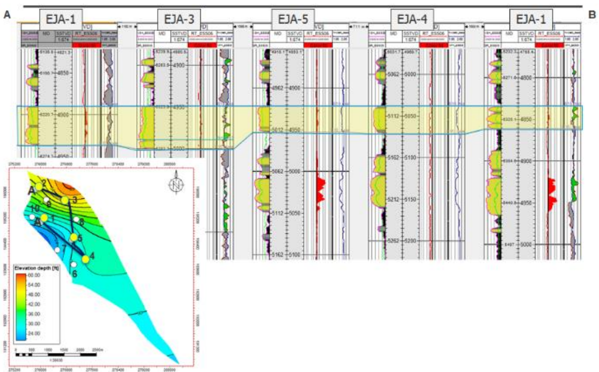

Fig. 20: E-15 Reservoir Stratigraphic Cross Section.

5. Conclusion

Seismic interpretation revealed that traps include highly faulted, anticlinal structures, tilted fault blocks and unconformity traps on the flanks of the anticlines. Petroleum-system analysis indicates that mature source rocks are widespread, reservoirs are abundant, and structures are well timed for hydrocarbon entrapment.

The reservoir characterization revealed that thereservoir Sand E-21 unit have a gross pay thickness varying from 138 to 212 feet, average effective porosity ranging between 26% and 32%, average volume of shale varyingbetween 6 and 10%, average net-to-gross ranging between 0.71 and 1.0.

The petrophysical evaluation shows that the E-15 Sand unit have a gross pay thickness varying from23 to about 57 feet, with net-to-gross varying between 0.72 and 1, average effective porosity ranging between 15% and 22%. The obtained Hydrocarbon prospectivity of the study area was evaluated through the vertical and lateral distributions of the petrophysical parameters and isoparametric maps of the reservoir properties (gross thickness map, net-to-gross and effective porosity). These maps reveal that the E-15 Reservoir has gross thickness, NTG and porosity increasing in the North-east direction. E-21 sand quality diminishes towards the structural high in EJA-1. E-15 is a low resistivity sand and its quality diminishes towards the structural flanks in EJA-1 and EJA-2.

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