NFW Potential of the Early Accommodation Deepwater Sands (EADS) Reservoir in Etim Field, NNPC/MPN JV Acreage, Offshore Nigeria

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ABSTRACT

With over 50 years of production, Etim Field is a mature field within the NNPC/MPN JV acreage. Extension of field life is largely dependent on infill drilling and new discoveries that can be developed profitably. The EADS reservoirs are turbidities with origin as remobilized locally-sourced Biafra sands that were deposited by sediment gravity flow processes in topographic lows immediately after the BQI (Base Qua Iboe) shelf collapse. The origin and production impact of this largely under-studied reservoir is examined with a view to highlighting them as viable NFW targets within the JV and similar depositional environments. Higher than expected oil recovery from some EADS reservoir compartments suggests that these reservoirs are of excellent quality and in good communication with the deeper Biafra reservoirs. This observation is critical in estimating remaining potential for future drill wells. Results from the stratigraphic and structural evaluation of the EADS reservoir were integrated with the sub-regional tectono-stratigraphy of the JV to arrive at an understanding of the origin and reservoir characteristics of these reservoirs. Data from studied wells show that they differ in origin from the younger IQI deepwater sands deposited above and older Rubble Beds in the JV. They occur locally where deposited i.e. they are not laterally extensive when compared to the IQI sands i.e. but individual deposits have significant thickness with average of about 120 ft. Excellent connectivity is observed within reservoirs compared to the DB sands. A combination of their excellent reservoir properties and occurrence below the thick Qua-Iboe shales makes this play potential NFW targets.

Keywords: Base Qua Iboe - BQI, Intra Qua Iboe - IQI, Joint Venture – JV, Near Field Wildcat – NFW, Disturbed Biafra Sands/Rubble Beds – DB Sands

INTRODUCTION

The Etim Field is located in the Southern part of OML 67 (Figure 1), operated by MPN on behalf of the NNPC/MPN JV. Production is primarily from the Zanclean - Messinian aged Biafra Reservoir systems - a bedded shallow water system consisting of tidal/fluvial influenced deltas and shoreface deposits. A secondary reservoir system, the prolific Intra Qua Iboe (IQI) reservoirs also exists in a few fields close to the south western limit of the acreage, they are the confined to weakly confined deep-water channel system of Piacenzian age. Together, these reservoirs have been the subject of multiple studies conducted by MPN and its operating partners. Findings from these studies have provided in-depth subsurface understanding required for the optimal development and management of the reservoirs which have ensured the profitable long-term production of the assets within the acreage.

A largely understudied but equally prolific reservoir system also exists within the acreage, they are Early Accommodation Deepwater (EADS) reservoirs. In the JV, they occur stratigraphically between the younger Piacenzian IQI Deepwater reservoir system and older Biafra reservoir system (made up of bedded and rubble bed reservoirs) (Figure 2). Previous authors have classified them as being part of the Rubble Beds but this study will highlight gross differences between the Rubble Beds and EADS reservoirs to classify them as two distinct reservoir groups. Also, observations from the study of the reservoir in the Etim Field highlight their excellent reservoir qualities, hence their potential as worthy NFW targets.

The EADS Reservoir

Hydrocarbon 'exploration' within already producing intervals is uncommon due to a generally held belief that static and dynamic information gathered from reservoirs in these assets over years of production has provided the much-needed subsurface understanding for the sustained

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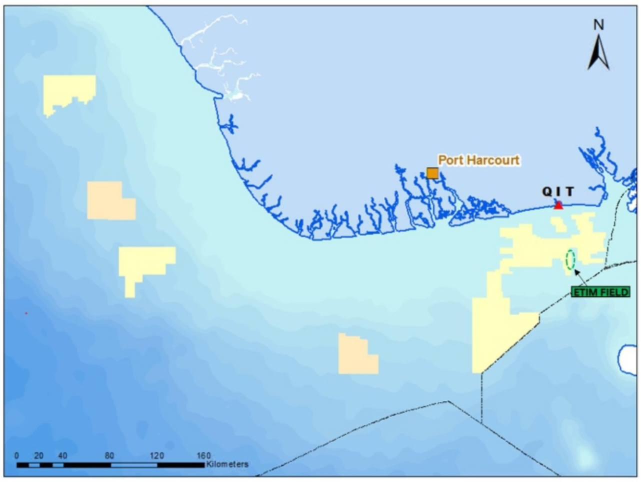

Figure 1: NNPC/MPN JV Acreage Map (Etim Field is highlighted).

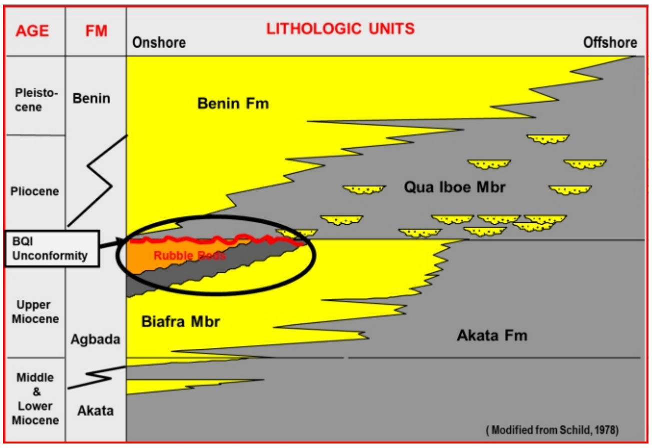

Figure 2: Stratigraphic section of the South East Niger Delta showing unique members of the Agbada formation present in OML 67 (Modified from Schild, 1978; after Joiner *et al.,* 1999).

development of these fields. This is especially common in fields like Etim from which a wealth of information spanning over 50 years has been gathered.

Due to their occurrence immediately below the IQI 500 sequence boundary, which is the deepest sequence boundary of the younger deep-water system (Figure 3), the EADS reservoir has previously been thought to be a component of the older bedded reservoir system – the Rubble beds, a name given to deposits within the acreage that are known to originate from erosion and remobilization of the older bedded system during the 4.2 Ma shelf collapse. The reservoir was discovered in the field in 1969 by Well 03 and had been the primary objective of just 2 out of the 6 wells that eventually developed the reservoir. The other 4 wells were targeting the deeper bedded reservoir system and encountered oil in the EADS reservoir.

This study highlights the opportunities that could exist in producing assets that can only be uncovered with an improved understanding of tectono-stratigraphic processes that set up the petroleum geology of the province or locality. While this knowledge may go against established knowledge of these areas, evidence from re-interpretation of existing data supported by global analogues is the key to pushing this new knowledge through.

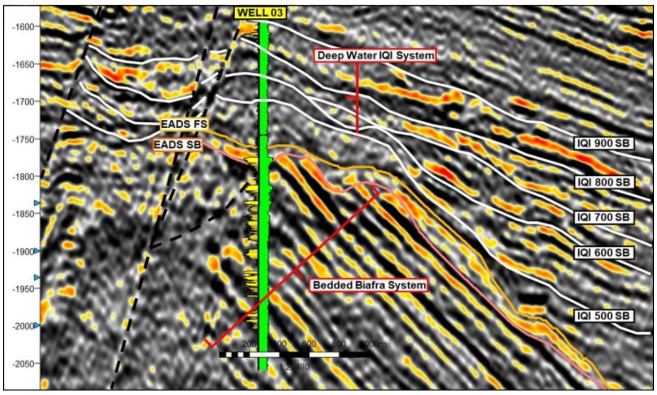

Figure 3: Seismic section showing producing reservoir intervals in OML 67, NNPC//MPN JV (Well 03 discovered the EADS sand in 1969).

METHODOLOGY

The analysis begins with a literature review of previous work carried out on OML 67. This was required to digest existing knowledge on the tectono-stratigraphic framework of the acreage with a view to understand the geology of the EADS reservoir.

Interpreted framework surfaces were translated to seismic and mapped across the entire field. Amplitude extractions, isochrons and frequency decomposition maps were generated and analyzed to identify channel geometries that may exist within the interval. Identification of channel forms are critical in differentiating the EADS reservoirs from the rubble beds based on their differences in genetic origins.

Core data from a single cored EADS penetration Well 19 was analyzed to identify sedimentary structures representative of the deep-water depositional environment. This was compared with core data from known rubble bed penetrations in other fields within the acreage. Core data from Ubit Field (OML 67) was also reviewed.

Production data from EADS completions was reviewed and compared with that of known rubble bed completions in Ubit Field as further evidence to support the difference in reservoir qualities between the EADS and known rubble bed producers. The "disorganized" nature of the rubble bed deposits implies the co-existence of reservoir and non-reservoir facies within proximity in the reservoir thus creating an effect of stratigraphic compartmentalization and a tortuous flow path for hydrocarbons towards perforations.

The following datasets were used in the study i) A 2010 3D Seismic dataset ii) Logs from 30 bedded well penetrations in Etim field iii) Core data from Well 19 iv) Logs from 20 IQI well penetrations in Etim field. V) Logs from 2 reservoirs of similar origin as the EADS reservoirs outside the Etim field VI) Cumm. Production data from EADS completions VII) Cumm. Production data from rubble bed completions in Ubit Field.

RESULTS AND DISCUSSION

A. Observations from Seismic Interpretation

The seismic expression of the EADS sand is generally consistent across the field. It is seen as a multi-cycle high amplitude seismic event very similar in seismic expression to the IQI sands deposited above.

Its relationship with the Biafra sands however is not consistent. In some areas it is seen to have an onlapping relationship with the rotated Biafra blocks below (Figure 4) while in other areas it is seen to be erosive. (Figure 5).

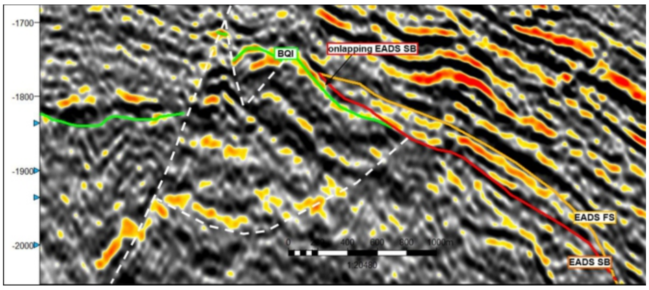

Figure 4: Onlapping relationship of the EADS reservoir with rotated Biafra blocks below.

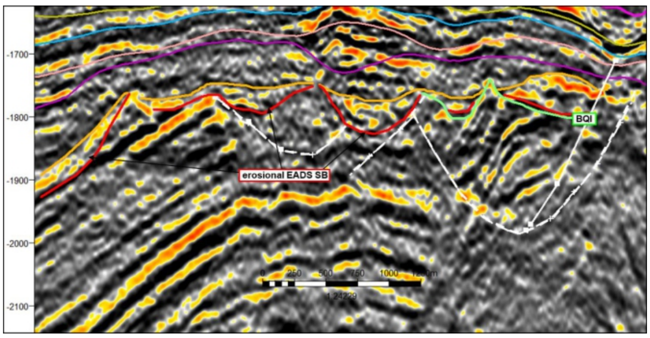

Figure 5: Erosive relationship of the EADS reservoir with older Biafra deposits below.

B. Reservoir Properties (comparison to Rubble Beds)

Observations of genetic rubble bed sequences in Logs (Figure 6) show the following:

i) Log pattern characterized by rapid facies changes
ii) Individual flow units are not correlatable between wells due to the disorganized depositional patterns
iii) Strongly heterogeneous packages (alternating sands and shales)
iv) Average NTG of Rubble bed perforations is 55%

In comparison, observation EADS well penetrations (Figure 7) and completions in Etim Field show the following:

i) Log patterns show consistent sharp base and mostly single unit blocky sands with well-defined marine shales from the top sand to the mapped flooding surface
ii) Sands proximal to each other and penetrating similar accumulation are correlatable
iii) Average NTG of genetic packages if 85% (no significant heterogeneity within genetic package)
iv) Production per well is >10 MBO, with the exception of Well 30 which produced 2.3 MBO and shut in on both HGOR and HBSW. Post shut in (S.I) analysis of this well showed that it was not optimally placed in the structure else it would have performed better
v) Wells generally produce for more than 5 years and S.I due to contact movement. This is despite the fact that Etim wells are not supported by simulation models, hence, they may not have been optimally

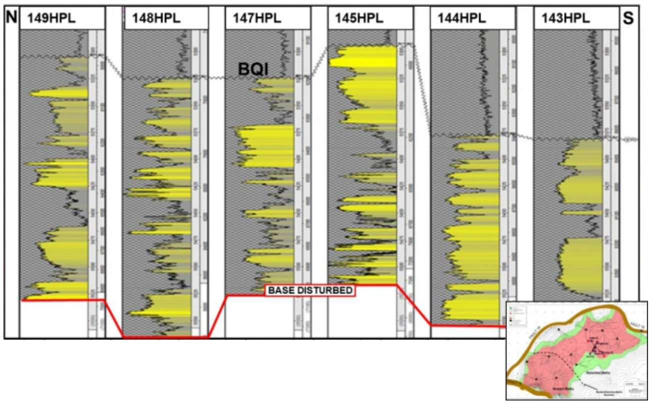

Figure 6: Well logs from select rubble bed penetrations in Ubit field.

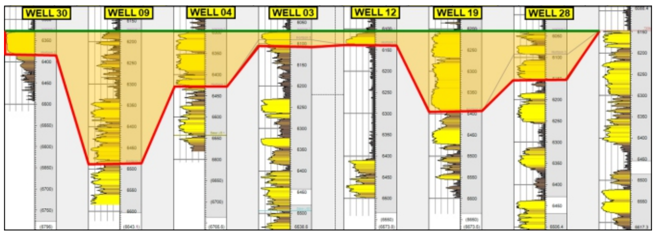

Figure 7: Well logs from all EADS reservoir penetrations in Etim field.

placed.

C. Core Data Analysis

Analysis of cores from Ubit Well 95, 55, 47 and 33 (Figure 8), and core from Etim Well 19 (Figure 9), show marked differences in gross sedimentary structures that help indicate different paleo depositional environments/genetic origins for the reservoirs they penetrated. These differences in genetic origins are strongly linked to depositional conditions for these reservoirs and are key factors that influence the overall rock properties and by extension well performance.

Observations of core data shows the key sedimentary features in the rocks, and their origins are explained. Some observations include:

- Floating sandy clasts – broken pieces of sandy Biafra rock in a sandy or muddy matrix.
- Broken shale beds – broken pieces of shaly rock in a sandy or muddy matrix.
- Micro-faulting and shear deformation – Related to internal stresses experienced by rock grains during remobilization.
- Poor sorting – the mutual co-existence of rocks with variable grain sizes.
- Significant mud matrix – a muddy transport medium or sandy sediments.

Observations from the Ubit Well 95, 55, 47 and 33 core clearly shows rocks that lack depositional characteristic of organized stratigraphic successions. The deposition of facie by erosional and subsequent remobilization in a rapid fashion without influence from known sorting medium is inferred here.

Analysis of the Etim Well 19 core photos show features characteristic of a submarine channel fill environment dominated by turbidites. Seismic line B – B' along the Well 19 trajectory (Figure 10), shows it penetrated a seismic facie with sub-horizontal bedding.

Key features observed in the Well 19 core include the following:

- Massive bedding – rocks void of primary sedimentary structures (seen in about 90% of the sands)

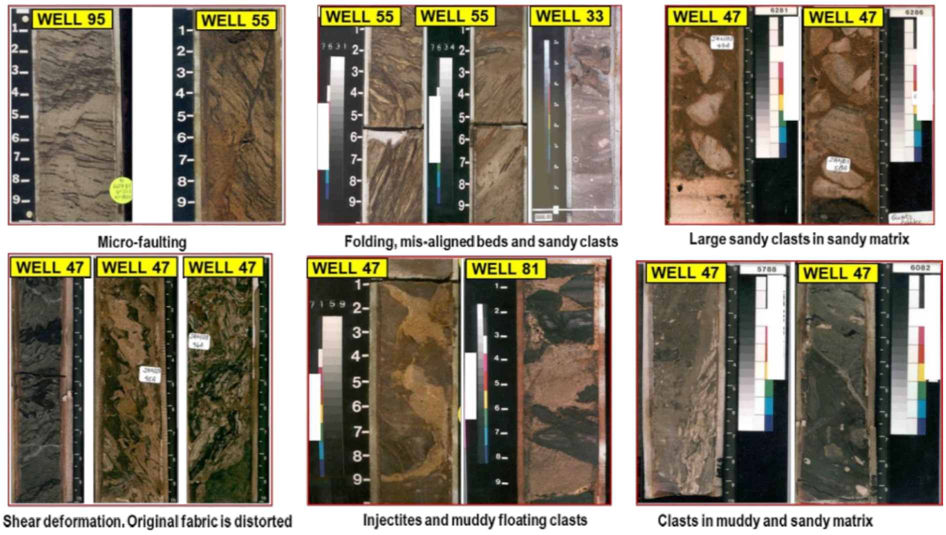

Figure 8: Core data from Ubit Wells 95, 55, 47 and 33 showing sedimentary structures in the rubble beds.

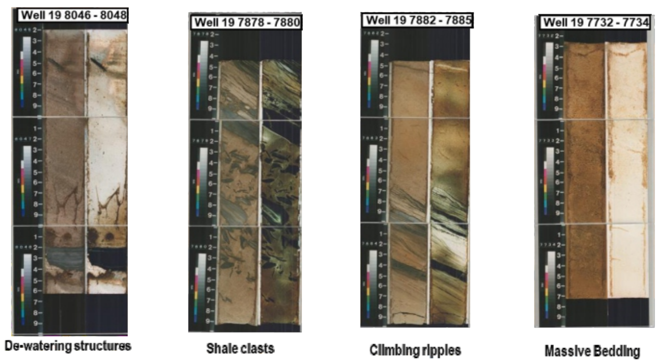

Figure 9: Core data from Well 19 showing sedimentary structures in the EADS reservoir.

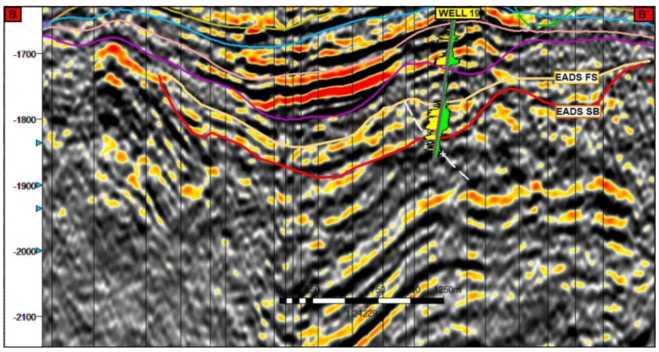

Figure 10: Seismic line along the Well 19 well trajectory showing the seismic facie penetrated by the well..

- Bi- directional climbing ripples – a feature of decelerating flows associated with river floods or turbidity currents
- Consistent dipping angles in finer grain sands and interbedded shales i.e. laminations
- Water escape structures – a feature consistent with the deposition of High Density Turbidites, according to Johansson and Stow, 1995
- Presence of shale clasts. Johansson and Stow, 1995 identified eleven different types of shale clasts in Deep Water Massive Sands which yield key information about the conditions of the host bed during deposition. They noted that they are dominant in High Density Turbidites.

Observation of core in Well 19 show a marked difference in sedimentary structures from those seen in Ubit cores, the primary structure seen here is massive bedding, seen in >80% of sand deposits. Massive bedding is consistent with deposition of high density turbidites. Compared to the sedimentary structures seen in the Ubit cores which show evidence for more cohesive type flows like debris flows.

D. Hydrocarbon Production from the EADS Reservoir

Figure 11 is a map showing locations of all historical EADS producers in the Etim field with insets of log motifs for these wells. Completions in EADS reservoirs are 7 out of 52 throughout the history of the field. Together, these completions produced 54.5 MBO, an average of 7.8 MBO/completion well. This compares well with the average 7.54 MBO/completion for the deeper bedded system and 8.5 MBO for the shallow deep-water system which are established excellent reservoirs.

Also, Well 09 completed in EADS accumulation AA produced 15 MBO out of an estimated 22 MBO. With a 68% recovery factor, a recovery factor higher than any known producer in the entire acreage and one even above global analogue for water drive reservoirs, production from Well 09 is thought to also come from the BB13 which the EADS reservoir erodes into (Figure 12).

The exceptional performance of these completions show that the EADS reservoirs are in good connectivity with adjacent reservoirs which they either erode into or are juxtaposed against. Thus, these reservoirs can aid the drainage of larger tanks leading to better economics for development of fields where they exist.

E. EADS Reservoir Exploration Opportunities

The EADS reservoirs are deposited in topographic lows immediately above the Base Qua Iboe (BQI) unconformity. These lows developed immediately after

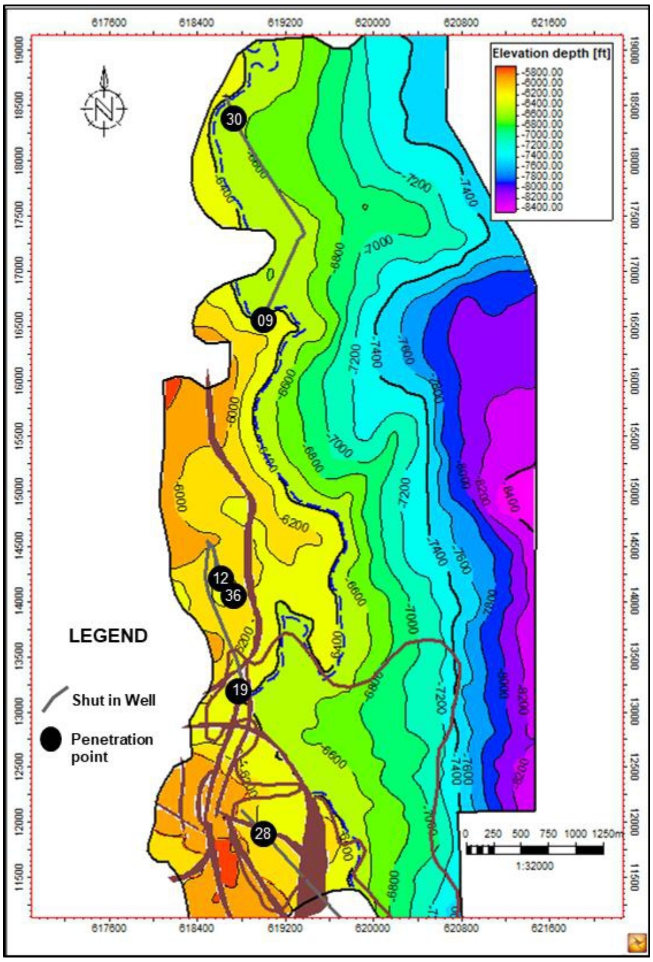

Figure 11: Map showing locations of all historical EADS producers in the Etim Field.

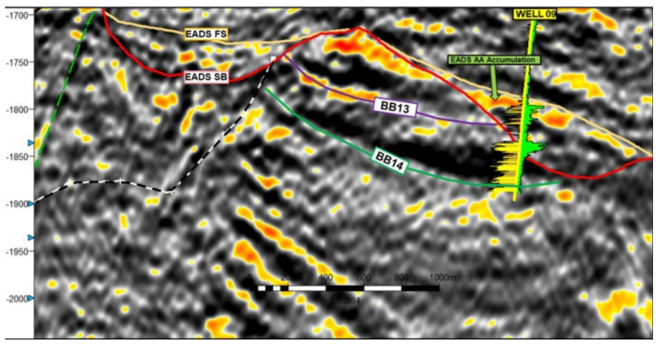

Figure 12: Line of section along Well 09 showing erosion of EADS reservoir into the deeper bedded BB13 reservoir. Well 09 contributed to the depletion of BB13 reserves.

the 4.2 Ma shelf collapse as a result of uneven erosion by the EADS sequence boundary and/or preexisting topography post collapse. They are bounded at the top by the EADS FS which marks the first major transgression after their deposition. This interval is the top seal for the EADS sands. EADS deposits and accumulations occur in 7 main locations above the OWC in Etim Field. All but one of these locations have been penetrated by wells. The character and thickness of deposits vary. They also show varied seismic and log character, all clearly indicative of deep-water deposition i.e. thickest at their deepest point. The topographic lows have been labelled according to the well that developed them, with the exception of one that is yet to be penetrated (Figure 13).

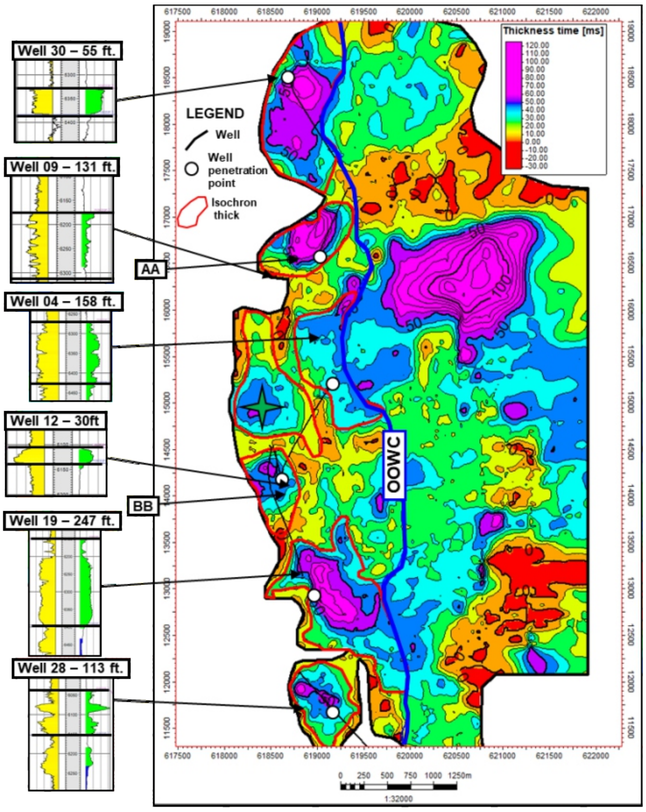

Figure 13: Isochron showing locations where EADS sands are likely to be deposited on the BQI. Sand presence and hydrocarbon was confirmed in all drilled locations.

CONCLUSIONS

The EADS reservoir system in Etim field had previously been classified as a component of the Biafra system known as the Rubble beds. Findings from this study show that it is of different origin as known rubble bed deposits within the acreage. Observations made from sedimentary structures and well performance highlight these differences.

The EADS reservoir has revealed itself as a world-class reservoir worthy of targeted NFW discovery. The processes that led to its deposition is not unique to the field hence it can be explored for in other fields within the acreage.

The analog MBDS reservoir deposited during the older 6.0 Ma scarlet collapse also shares same excellent well performance history as the EADS reservoir thus indicating that wherever this depositional process occurs a world-class reservoir will most likely result from it. This fact should excite explorationists working other areas in the Niger Delta who can look out for conditions that led to the deposition of this play(s) and carry out their exploration with a high degree of achieving success.

Tectono-stratigraphic frameworks do exist for all hydrocarbon provinces around the world. These frameworks are built painstakingly by geoscientists carrying out early exploration efforts in the area. They are as correct as the knowledge, information and interpretation skills available to them at the time and should be seen not as a final product but as one that is designed to be updated as newer information is gained. This mindset can open up a wealth of untapped potential within producing assets and is one that should be embraced by geoscientists.

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