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RESEARCH PAPER

DEEP PLAY PROSPECTIVITY OF U- FIELD ONSHORE NIGER DELTA BASIN

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ABSTRACT
This study Integrated structural interpretation with some aspects of regional stratigraphy concepts that allowed for the prediction of sand fairways and their gross depositional environment to evaluate the unpenetrated deep prospect of the U-Field onshore Niger Delta. Gross Depositional Environment model was established based on an integration of evidences from seismic, well data and paleo-bathymetric profile of wells within the area. Sequence stratigraphic analysis derived from an integration of both biostratigraphic data and chronostraigraphic chart, enabled the definition of an objective interval both on the strike and dip directions between 23.2 Ma MFS and 26.2 Ma MFS. This interval fell within the Shelf Margin Gross depositional environment with characteristic wedge-like gently dipping seismic facies geometry on seismic. The target reservoirs are sequences of potential LST/TST shelf margin sand packages which have a potential analogue along the strike direction. The prospect trap consists of a four-way dip closure with both a three way and two way components. The main risks identified for this prospect are reservoir presence and seal integrity. The geologic risk assessment result performed gave a possibility of success value of 0.4, which is considered acceptable at the exploration stage.

Keywords: *Deep-play, sequence-stratigraphy, exploration, U-Field, Niger-Delta*

INTRODUCTION

With the progressive creaming of the shallow and intermediate depth objectives in the Niger Delta Basin, the deep play (older stratigraphic sequences) constitutes the next exploration frontier beneath existing fields. These plays are mostly undrilled and underexploited in terms of prospects identified mainly due to seismic data quality below three seconds and sometimes due to overpressures limiting well total depth. Wells *et al*. (1990) originally defined the Niger Delta Deep Play as the combination of prospects and leads with untested structural closures in prospective sedimentary sequences beneath the presently penetrated levels. The major challenges associated with deep stratigraphic plays are reservoir presence, prediction and distributions (both on a regional and pro-

spect scale), degree of overpressure, seismic imaging and trap integrity. Several workers have adopted different technique to identify and evaluate deep prospect in the Niger Delta Basin. Beka and Oti, (1995) utilized Series of surface and volume attributes such as variance edge and sweetness attributes ran on a 3D seismic volume data to investigate potential structural and stratigraphic controls in order to gain understanding of some targeted features such as porosity, permeability and direct hydrocarbon indicators (DHI) for hydrocarbon exploration in the area.

Magoon (2004) carried out oil-and-gas-related investigations in a petroleum province within the Niger delta to locate deep undiscovered commercial quantities of petroleum and to determine the related risk, by using the petroleum -system concept to present known information and the complementary-play concept to present unknown information. He concluded that exploration risk can be more objectively determined with an integration of the play, prospect, petroleum system, and the complementary play concepts. Olaleye and Basorun (2006) applied high resolution sequence and seismic stratigraphy for the prediction of sand fairways and their environments of deposition in a field in the Niger Delta Basin. They achieved this by utilizing petro-acoustic analysis and multi-attributes inversion in seismic stratigraphy to predict with good probability, reservoir qualities and petrophysical parameters and their distribution within the area/volume of interest. Grant *et al*, (2008) adopted a multidisciplinary data approach that include Well logs, biostratigraphic data, seismic data and semblance map in the geological evaluation of deep hydrocarbon prospect FOB-Field, onshore Coastal Swamp Depobelt in the Niger Delta Basin. They were able to Correlation and establish the equivalent sands and continuity lithologic units for the targeted reservoir sands at the deep prospective area of the field. Onyekuru *et al*. (2012) working in "XB Field", of the Niger Delta Basin, integrated well logs and biostratigraphic data to carry out a sequence stratigraphic analysis of depositional systems in the field. They delineated and correlated good quality reservoir sands that reflect depositional systems deposited during different phases of base level changes. The low and High stand sands show good reservoir qualities while the shales of the Transgressive system tract could serve as potential reservoir seals in the field. These delineated sequences were discovered to be deposited within the Neritic to Bathyal paleoenvironments and are dated mid-Miocene (15.9 - 20.4 Ma) in age.

This present study applied an Integration of well based sequence stratigraphy evaluation and seismic data for gross depositional environment (GDE) study and summarizes the geological concepts, results and conclusions of a deep play exploration target beneath the existing U-fields in the Niger delta. The study field is a Partially Appraised Field and the entire region host several proven producing oil and gas fields. Hydrocarbons have been encountered in the field, between 6500ft and 10200ft. Only one well in the field reached a total depth (TD) of 12,333ft and encountered the 20.7MA MFS regional stratigraphic marker. A well in the adjacent fields identified hydrocarbon in the sequence below 20.7MFS and this offered further motivation towards exploring for deeper prospectivity in the U-Field.

MATERIALS AND METHODS

According to Catuneanu *et al*., (2009), sequence stratigraphy concept is uniquely focused on understanding the subsurface geology, analyzing changes in facies, geometry and distribution and ultimately determining possible reservoir properties character of strata and predicting these changes across field. Applying this concept, a sequence stratigraphic framework was built for depositional sequence identification and regional well correlation. Environment of deposition and key stratigraphic surfaces (Maximum Flooding Surfaces and Sequence Boundaries) were interpreted using biostratigraphic data (biofacies, P-zones and F-zones); parasequence stacking pattern, paleobathymetry data. These data together with the Niger delta Chronostratigraphic (Stacher, 1995), were used to constrain markers in time. The Gross Depositional Environment (GDE) model for the study was defined using an integration of evidences from paleobathymetric profile, log motif and seismic facie analysis.

The major part of the objective reservoir sequence in the prospect area lies in the Upper Oligocene - Lower Miocene (Fig. 1) between 23.2 Ma Maximum Flooding Surface (MFS) and 26.2 Ma MFS which has been penetrated in the V-field. Structural framework and top structured maps were built for the identified prospect from interpreted faults and horizons. The structured map produced aided with prospect of interest identification and volumetric estimation and evaluation. An appropriate velocity model/ function built from the available checkshot data in the field was applied to the identified prospect to depth convert the time surface to a depth.

The data set available for the study include biostratigraphy data, Well log data, check shot data, 3D seismic data.

RESULTS AND DISCUSSION

As observed in Fig.1, between MFS 23.2Ma and MFS 26.2Ma (sequence of interest), there exist an alternation of transgressive and regressive parasequences, but through time, it's an overall progradational pattern from the regional well correlation. It is observed that from the dip section there is facies progradation. Typically, in Z-0011, the channel sands down dip towards U-001, due to facie progradation, we expect to find thinner channel and shelf sands. From the strike correlation (Fig. 2), we observe the continuity of sands at both shallower and deeper sections within the interval of interest. Although there is a decrease in thickness in the hydrocarbon bearing sands from NE towards SW, the sands are laterally continuous and are expected to occur within the prospective interval.

Five major down to basin faults were mapped with 1and 2 being our faults of interest since they bound the structure of the study field. The dominant faults trend east-west, with signif-

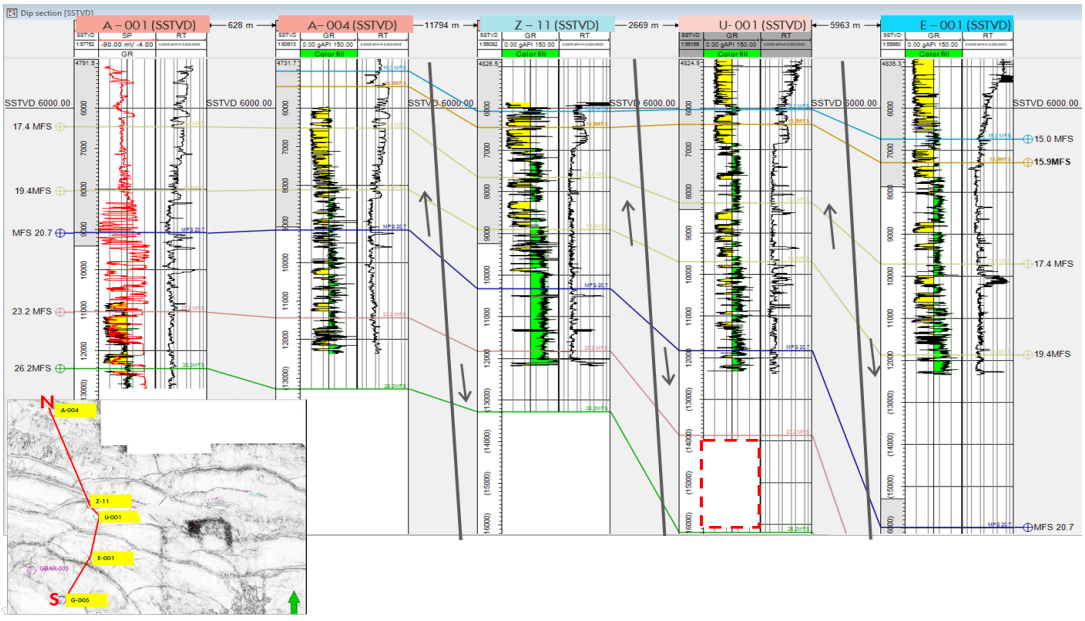

Fig. 1: Dip section correlation from North to South within the study area showing the consistent overall deepening and subsequent decrease in net-to-gross

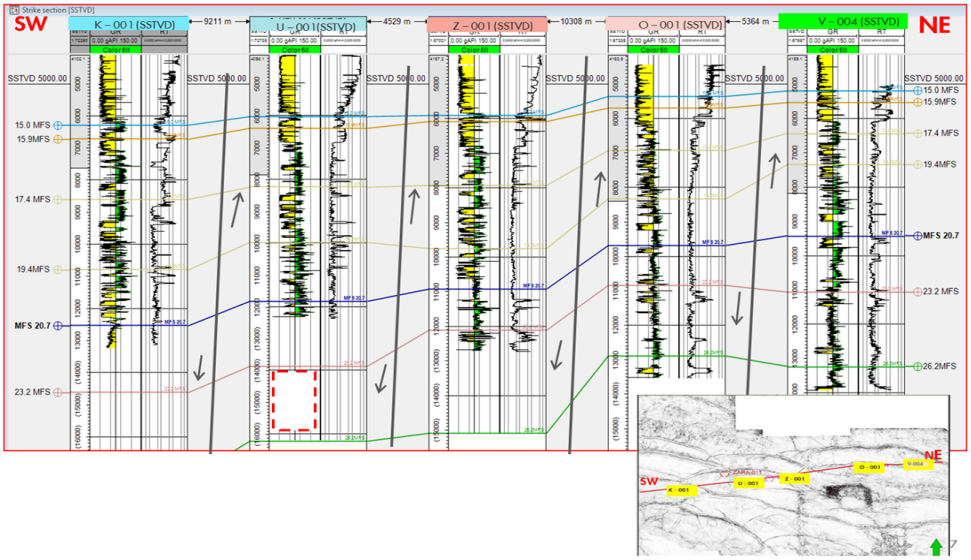

Fig. 2: NE-SW (strike) correlation within area of interest showing sand continuity at both shallower and deeper sections within the interval of interest

cant growth observable on the faults bounding the major fields; Z-Field, U-Field, E-field and G-Field. The main objective horizons and the various MFS from 15.0Ma MFS (shallowest) – 26.2MFS Ma were interpreted based on information from results of well-to-seismic tie. One target reservoir level (RSP2) was interpreted within the interval of interest as a near top and it lies conformably between the regional shale 23.2 Ma MFS and 26.2 Ma MFS (Fig. 3).

Several evidences were obtained from well, paleo-bathymetric, and seismic data to establish the Gross depositional environment. These evidences were further integrated.

For the first evidence, in the paleobathymetric information show in Fig. 4, the proximal wells A-001and A-004, both have paleobathymetric profile range within Middle Neritic – Outer Neritic, while the distal wells O-001, V-004 and Z-001, have profile within the Outer Neritic- Bathyal Zone. Thus our area of interest, the U-001 will most likely fall within the Outer Neritic – Bathyal Zone (Outer shelf - shelf edge).

The second evidence stems from Seismic facies studies conducted within and below the objective interval showed cyclic clear clinoforms with both down-lapping and top-lapping stratal patterns, interpreted to represent sand rich shelf edge deltaic sequences, characteristic of both HST and LST reservoir sands (Fig. 5). The depositional pattern within the objective intervals contains a series of repetitive cycles. The wedges within this cycle are interpreted as sand prone units of shelf edge deltas, deposited during periods of relative seal level fall while the continuous reflectors are thought to be shale-prone packages representing episodic transgression of paleo shelf edge.

The third evidence was observed in the Seismic reflectivity character through a regional dip transect of the 3D seismic from A-004well on the north to E-001well revealed different seismic facies characters indicative of separate gross depositional environments (Figs 6 and 7). The seismic facies interpretation and the subsequent depositional environments are given below between 0-1500ms shows a discontinuous low amplitude somewhat chaotic reflection

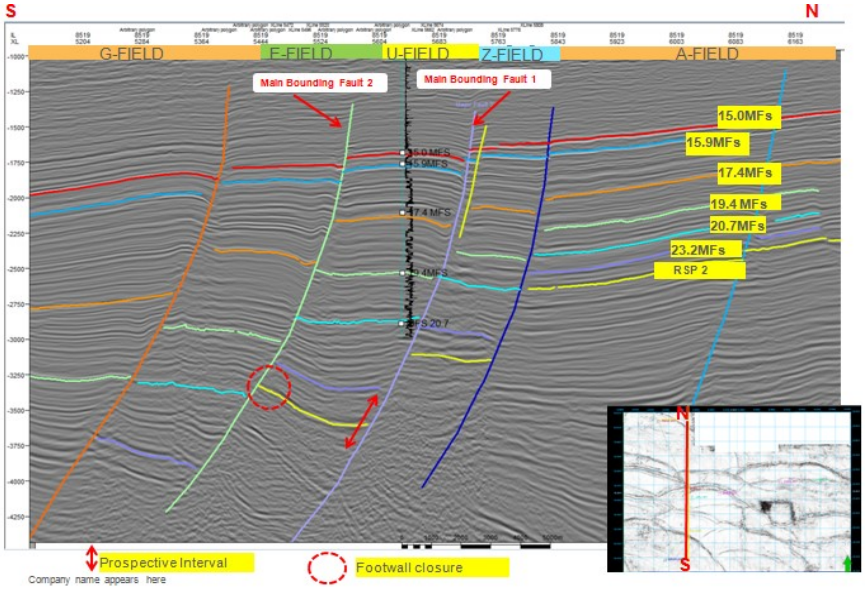

Fig. 3: Regional interpreted representative seismic dip line across the prospective interval

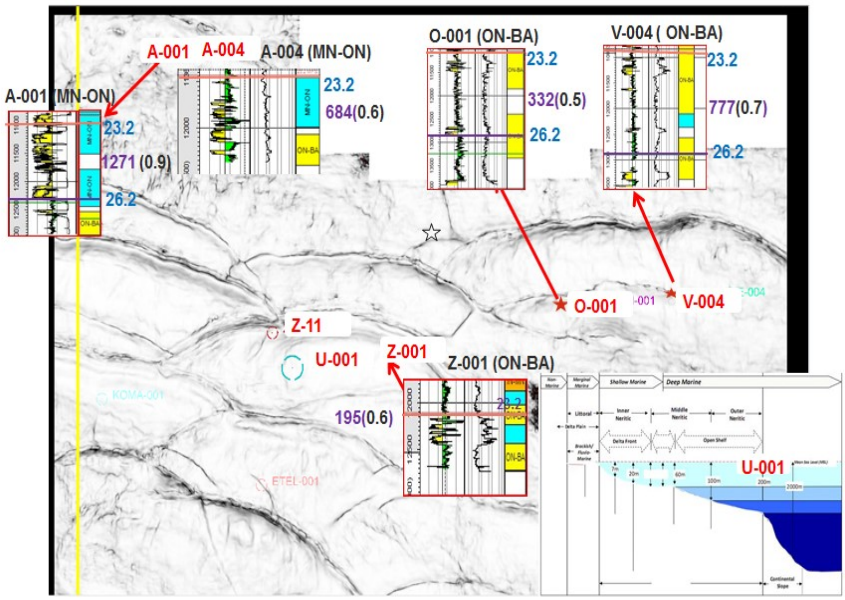

Fig. 4: Paleobathymetric information of key wells

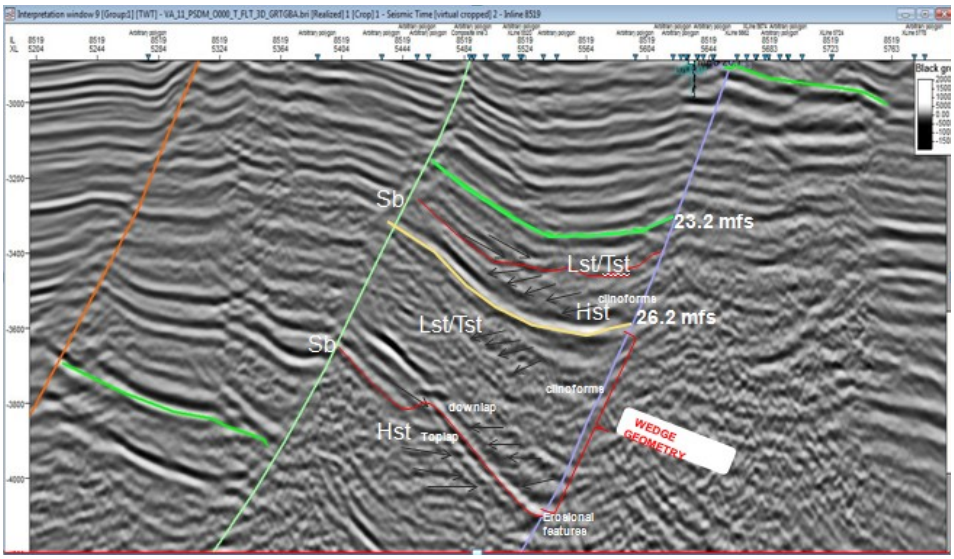

Fig. 5: Seismic facies analysis of wedge like geometry and downlapping clinoform suggesting shelf-edge geometry

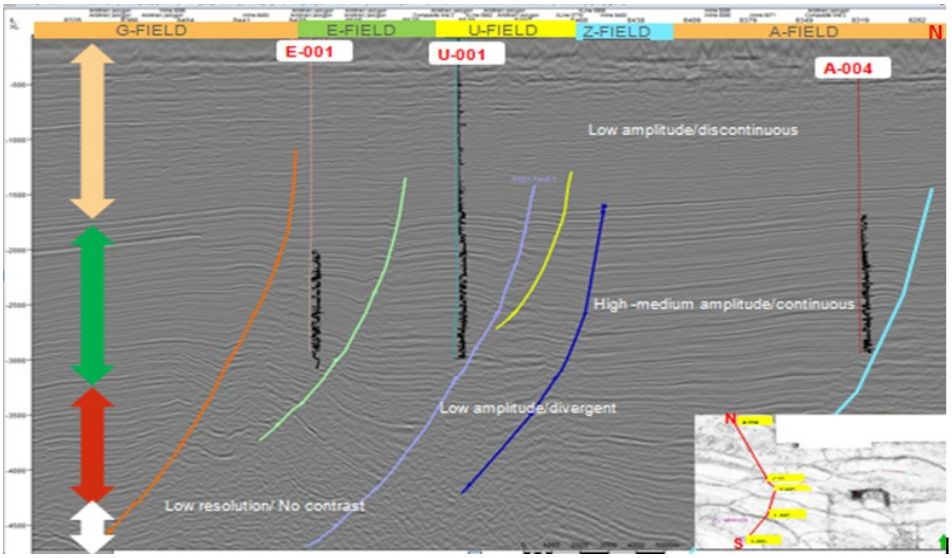

Fig. 6: GDE seismic facies analysis of interaction between reflectivity and stratigraphy

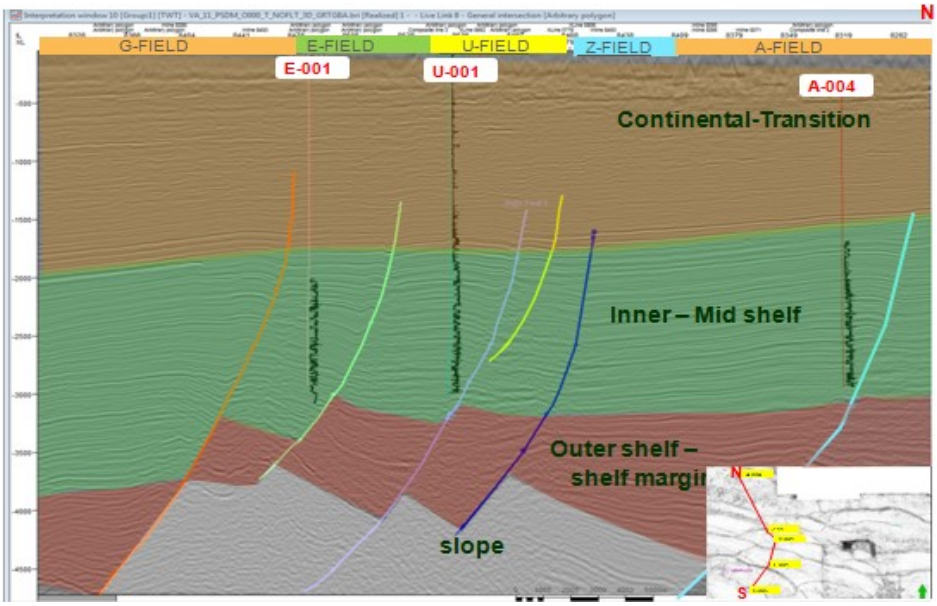

Fig. 7: GDE seismic facies model for the study area

character punctuated by discontinuous high amplitude events. From the superimposed logs, a high net to gross which conforms to no change in acoustic impedance is observed. This seismic reflection character is characteristic of the continental-transitional environments (Benin Formation). Between 1750ms -3000ms, a high – medium amplitude parallel continuous high frequency reflections; the decrease in net/ gross from the superimposed logs conforms to high acoustic impedance contrast. There exist no inclinations of reflection or divergence. These are characteristic of the inner to mid shelf (Shoreface) environment. Below 3000ms, a relatively low amplitude discontinuous and continuous events with the presence of divergent inclined reflections, low-medium acoustic impedance contrast, which are characteristic of outer shelf margin environment (Shelf Edge Delta's). The discontinuous low frequency dipping seismic reflections characteristic of slope environments. Thus, integrating all these evidences, it is inferred that the study area lies within the Outer Shelf - Shelf margin environment.

Depth surface was generated from the interpreted horizon of RSP2 prospective reservoir **(**Fig. 8**)**. The prospect structure closes against the hanging wall of the Z-Field - U-field boundary fault which runs approximately east-west just north of the U-field and also against the U-E Field bounding fault. The prospect is a four way dip closure with both a three way and two way components defining the low (P10), base (P50) and high case (P90) respectively (Fig. 8). The prospective reservoir is a seismically defined lowstand wedges wedges believed to have been deposited in a shelf margin setting with marked down-lapping clinoforms. The wedges consists of medium amplitude seismic reflectors; these thickens against the main bounding fault and tapers out to the south (bounded top and below by a set of continuous bright amplitude reflectors.

Chance factor assessment (Geological risk analysis) was carried out for the various play elements (charge, reservoir prescence, structure and seal) to estimate the geological possibility of success attached to the RSP2 deep prospect.

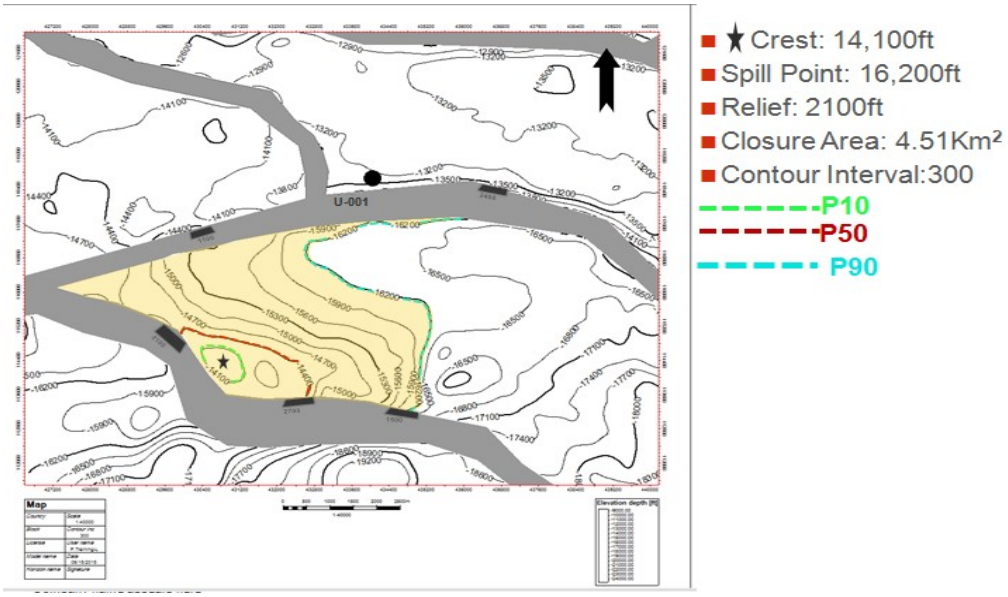

Fig. 8: Depth structure map for RSP 2 showing low, base and high case prospect closure

The charge potential for the Tertiary Niger Delta is generally considered a 'given' with wide variety of possible source rocks from the Paleocene to Miocene marine Akata shale. Migration or re-migration is however a significant risk worth considering. For the identified reservoir seal pairs, the Possibility of Success (POS) for a mature source is placed as 0.99 (99%). This is mainly because the U-Field area is surrounded by proven fields and discoveries (A-Field, Z-Field and E-Field) and the likelihood of vertical migration up the down-to-basin fault exist.

Top seal for the prospective area was provided by regionally mapped continuous shales representing periods of marine transgression (maximum flooding surfaces). The 23.2 Ma event seals the overall lowstand wedge systems being a major geological flooding event when large quantities of very fine marine shale packages were deposited. The Possibility of success for seal effectiveness is placed at 0.80 (80%) for RSP 2. This is because it is expected that the outer neritic environment poses a low net to gross when compared to seal presence and this could lead to good top seal.

Key observations of seismically well-defined wedge geometries due to rapid thickness changes along the main growth faults in the objective interval, coupled with an overall basinward thinning of gross interval suggest that the prospect is close to the Paleo shelf edge. The Possibility of Success for reservoir presence of the RSP 2 here mapped is placed at 0.70 (70%), because although favorable seismic facies character and GDE suggests potential LST/TST shelf margin sand sequences, distance to the analogue used (V-001&004) is over 21000m.
The possibility for a structure was given and placed at 0.75 (75%), this stems from the presence of a valid structure in the top structured map (Fig.8).

Geologic Possibilty of success for the prospect was estimated by multiplying the defined chance factors for each play elements summarized in Table 1. The geological possibility of success was estimated to be 0.4. This value

Table 1: Risk template for various play elements

RISK ELEMENT	PROS	CONS	RSP 2 RISKING ITALIAN FLAG	CONFIDENCE LEVEL	LIKELI-HOOD	CHANCE FACTOR
Structure	Presence of valid closure on time and depth	Quality of seismic could impact on trap imaging Relative timing of trap formation before migration Limited control on velocity variation from seismic		**HIGH**	**LIKELY**	**0.75**
HC Charge	U-field is surrounded by proven economic discoveries Presence of shallow hydrocarbon discoveries in the U-Block, are evidences of migration Sands within the same GDE are hydrocarbon bearing	Presence if migration route and generation of hydrocarbon before trap formation Presence of Non amplitude supported play		**HIGH**	**LIKELY**	**0.95**
Reservoir	Predicted reservoir presence was conformed from recognition of down-lapping clinoforms Presence of sand continuity on regional well correlation	No well has penetrated that interval between the U-Block Quality of seismic could impact reservoir imaging Distance to analogue 20.148m		**HIGH**	**LIKELY**	**0.70**
Seal (Fault Seal & Top Seal)	High top seal availability since reservoirs are capped by thick shales (MFS)	Potential for leakage associated with faulting (low lateral seal)		**HIGH**	**LIKELY**	**0.80**
Source	The widespread occurrence of Akata formation, the known hydrocarbon source rock across the Niger delta			**VERY HIGH**	**VERY LIKELY**	**0.99**
		GEOLOGICAL POS				**0.4**

exceeds the threshold value of 0.3 that is acceptable at exploration stage where no well has been drilled for further appraisal study.

The key uncertainties identified for any first pass volumetric estimation will include Hydrocarbon Column Height and Net to Gross Ratio. Uncertainty associated with hydrocarbon column height resulted from the fact that the structure is partially fault dependent. Based on shallow hydrocarbon discovery studies within the area, the hydrocarbon column height of between 700ft and 2100ft can be adopted. Given that the objective reservoir units are largely unpenetrated, there exist some uncertainties on the properties and quality of these reservoir units. The V-field containing V-001& 004 which penetrated Shelf Margin deltas can be used as analogue to constrain the NTG distributions and mean values.

CONCLUSIONS

This study has highlighted the importance of sequence stratigraphy as an exploration tool in deep geological settings. The stratigraphic correlation along the depositional strike was useful for identifying a regional analogue for the deep reservoir rock units beneath the field in the study area (which are un-penetrated).

The importance of defining the Gross Depositional Environment (GDE) for any objective depositional sequence was also highlighted as it is a significant way of de-risking a prospect in terms of reservoir properties which could strongly affect prospect volumes. After evaluating the chance factor of each play element, the integrated study attached a geological possibility of success of 0.4 to the RSP2 prospect, which exceed the 0.3 threshold for an undrilled prospect.

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