A Multi-Scaled Approach to Time-Depth Conversion, in a Geologically Complex and Variably Mature Hydrocarbon Acreage

Ifekelunma Umeogu, Bart Tichelaar, Obobi Onwuka, Adelola Adesida, Chibuzoe Chejieh, Obinna Chudi, Johnbosco Uche and Reginald Jack
The Shell Pretroleum Development Company of Nigeria Limited

ABSTRACT

Conversion of seismic data from its native domain (2-way reflection time) to depth domain (true vertical depth) is a required geophysical activity for geological interpretation, in-place volumetrics estimation, safe well design and drilling execution. Within a single acreage, "near-field" opportunities may not share geological similarity, are not-so-near to neighboring fields, nor benefit from proximal, well-caliberated producing fields. Hence, adopting a one-size-fits-all bepth conversion perspective for the evaluation of such opportunities will lead to unrealistic representations of the subsurface. It is therefore essential to properly utilize the geological controls of each opportunity, while recognizing that these controls can differ throughout the acreage. This work considered the above-mentioned in the concurrent and rapid maturation of four hydrocarbon opportunities spread across 580 km2 acreage, which necessitated a two-phased, tailored depth conversion approach. For a consistent and comprehensive subsurface understanding, two sub-regional models were developed in the initial phase, to capture the prospect spread and the depositional variability observed across the acreage. These models incorporated seismic velocities and were calibrated by mapped regional events and well tops. In the later prospect focused phase, a single, local depth conversation model was built from nearby (3km) well velocities for in-depth understanding of a specific opportunity. While suitable for this single prospect , this approach would underestimate uncertainties for other opportunities that are farther away from existing wells. A clear success of this multi-scaled approach was the delivery of credible, consistent, and scaled depth models in a timely manner. This led to the de-risking of all targeted prospects and the identification of significant recoverable gas resources. Additionally, this illuminates the impact of data calibration on mitigating-depth uncertainly - as seen in the drop in uncertainly ranges from a maximum of ±400ft (sub-regional approach) to a maximum of ±50ft (nearby well-based approach), for the same prospect.

Keywords: Data calibration, Subsurface uncertainty, Depth conversion, Geological models, Seismic, Regional mapping, Prospect evaluation.

INTRODUCTION

This study area is 580 km2 in area and has been split during this evaluation into two major sections, based on the observed difference in geological setting (Figure 1).
a. The northen area (350 km2): no producing field, 6 exploratory wells drilled, and 2 prospective opportunities.
b. The southern area (230 km2): 1 producing field, >40 wells drilled (exploratory and producing) and 2 prospective opportunities

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INTENT AND BUSINESS DRIVERS

SPDC's desire to rapidly identify and supply significant gas volumes in the near-terms, which would utilize capacity available in the nearby gas plant and ultimately enhance NLNG supply security. This is the business motive underpinning the effort for identifying and maturing gas reserves in these assets.

The intent of this technical work was to generate fit-for-purpose time-to-depth conversion models for the simultaneous maturation of multiple opportunities across the acreage, adopting appropriate methodology to meet maturation objectives.

APPROACH/METHODOLOGY

Data utilized for this work included the following:

a. Well data from relevant wells across the acreage. The included:
   i. Tops - Maximum Flooding Surface

(MFS) picks based on biostratigraphic data (Tortonian. 1 (Tor. 1))/10.4 Ma), Serravallian .3 (Ser. 3)/11.5 Ma and Serravallian .2 (Ser. 2) 12.8 Ma) and reservoir tops.

ii. Petrioghysical well logs.

iii. Well velocities.

b. QGod interval velocity seismic volume which spanned the entire acreage.

c. Fault interpretations.

d. Mapped horizons for the MFS picks and the reservoir tops used for time-depth model.

The scope and approach to undertaking this work was as follows:

a. Build two sub-regional depth models based on mapped horizons, scale seismic velocities and well data, to enable Play-Based-Exploration (PBE) across the entire area. PBE is an approach for evaluating exploration opportunities in a holistic manner at basin, play or prospect scale, for the screening of multiple opportunities. Two sub-regional depth models are necessitated due to the observed geological variability between the northen and southern parts of the acreage.

b. Build a field-specific depth model based on well velocities, to evaluate the Adi opportunity, which is in the northern area. The Adi field is a near-field opportunity which benefits from having native well velocities in one of its wells - the Adi-002 well.

Following each model generation, the results were analyzed, and the related depth uncertainties were evaluated using a 2 standard deviation range, which is statistically robust to capture uncertainties.

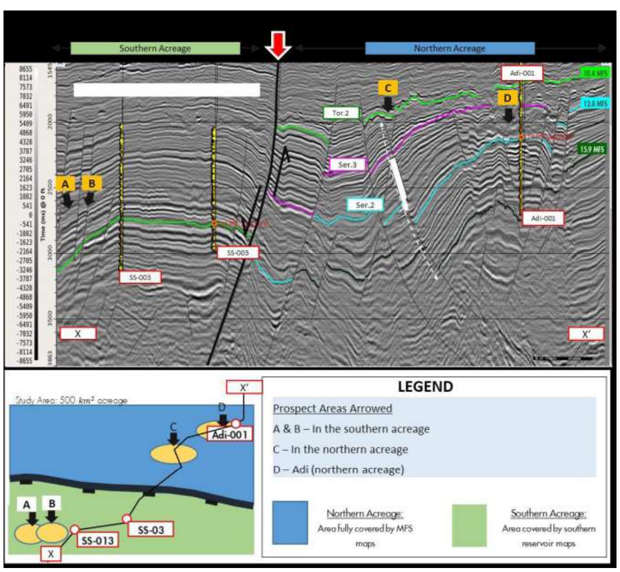

Figure 1: A section through the acreage which traverses both the northen and southern sections. The geological character is observed and interpreted to show the major bounding fault which separates north and south and significantly downthrows the southern section.

RESULTS AND DISCUSSION

Following the sub-regional evaluation of this acreage, it is understood to be predominantly of Miocene age, with structural styles which are typical of the extensional setting of the Niger Delta i.e, gravity-dominated, syn-sedimentary structures. The grass depositional environment analysis places it is a shelf to slope palaeo-environment. Hence, shelf deposits are expected to have (in a broad sense), good lateral continuity and similarity in depositional facies, which is advantageous to the approach applied here for time-depth conversion.

In this section, the outcome of the two-pronged approach to generate three depth models is discussed.

a. Scaled Seismic Velocity Model for the Northern Area, Based on Regional flooding Events

Regional MFS maps (Tor.1, Ser. 3 and Ser .2) were used as calibration for this model, together with the seismic interval velocity volume and well data from Adi-001, Adi-002, NE-001, N1-001 (Figure 2)

The Ser. 2 MFS which is the deepest sub-regionally correlatable MFS in the acreage defines the base of the

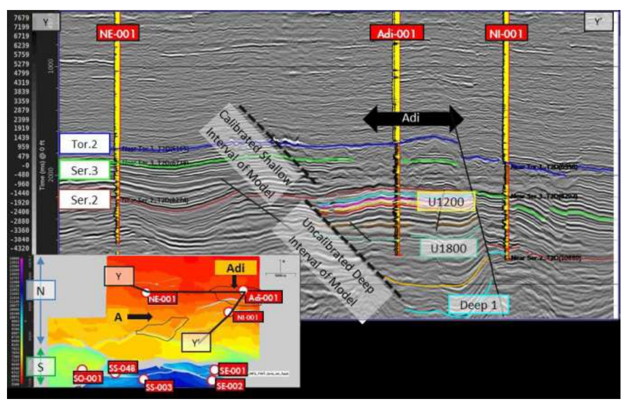

Figure 2: Image shows a traverse across the northern area, distinguishing between the calibrated and uncalibrated intervals of the model, and highlighting some of the objective reservoirs in Adi field.

calibrated interval of the model; however, the Adi field only has target reservoirs in the uncalibrated interval of the model.

b. Scaled Seismic Velocity Model for the Southern Area, Based on Mapped Reservoir

In this model, sub-regionally extensive reservoir maps (D5000, E5000 and E9000) were used as calibration for

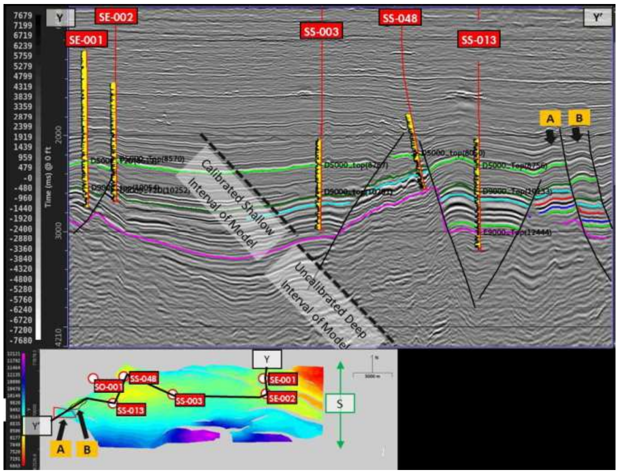

Figure 3: Image shows a traverse across the southern area, distinguishing between the calibrated and uncalibrated intervals of the model, and highlighting some of the objective A and B prospects.

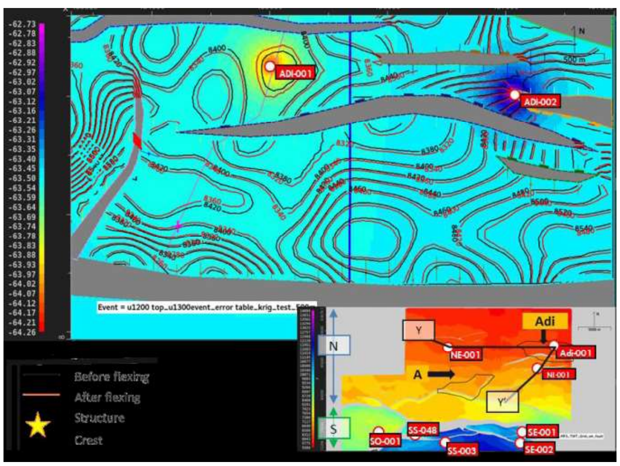

Figure 4: A map sowing the impact of local well-based velocity on the U1200 reservoir top structure map.

Table 1: Summary of uncertainties estimated in the 3 models.

	Model	Uncertainty Range (Feet)	
		Calibrated Interval	Uncalibrated Interval
1.	Scaled Seismic Velocity Model-northern	261	300-400
2.	Scaled Seismic Velocity Model-southern	93	N/A
3.	Local Well Velocity Model - Adi Field	50	N/A

this model, together with the seismic interval velocity volume and well data from SE-001, SE-002, SS-003, SS-048 (Figure 3).

Due to seismic imaging and well calibration available, the E9000 reservoir is the deepest reservoir identified in this area and it defines the base of the calibrated internal of the model. The A and B prospects have its target reservoirs in the calibrated interval of the model.

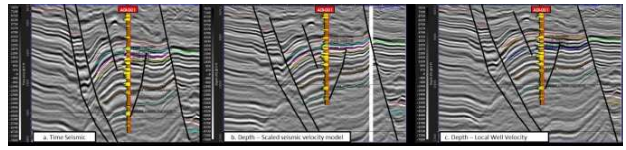

Figure 5: a. image showing seismic and interpretations in time domain. b. image showing seismic volume and interpretations displayed with scaled seismic velocity model, U100 event - 300ft deeper, U1800 event - 350ft deeper than well top. c. image showing seismic volume and interpretations displayed with local well velocity model. Excellent match of depth seismic, well picks and interpretations.

c. Local Well Velocity Model for Adi Opportunity Maturation

This as focused on achieving on improved depth model in Adi, based on the nearby Adi wells, which had acquired well velocity data.

Comparing the outcome of the 3 models, the following errors margins were estimated, as shown in Table 1.

Both sub-regional models shared are driven by the same intent, based on the same methodology and applied within (largely) the same area. However, we see significantly different depth uncertainty ranges due to more data in the southern area.

The local well velocity model brings an even stronger control to the depth, calibration. Hence, the Adi opportunity benefits from scaled error margin, where it only retains 15% of the initial error margins which the comparable uncalibrated interval of the scaled seismic velocity model had (Figure 5)

IMPACT AND CONCLUSION

Considering the three models applied, we observe the huge impact of data calibration in mitigating depth uncertainty- as seen in the stepwise improvement in the confidence of our depth models uncertainty ranges, from a maximum of +400ft (scaled seismic velocity model approach) to +50ft (local well velocity model approach). Although the same approach of scaled seismic velocities was applied to generate sub-regional models, the availability and spread of data in the southern area was the underlying factor to lowered depth uncertainty. The application of local velocities in Adi field further significantly reduced the depth uncertainty for the Adi opportunity compared to both sub-regional models.

Not all exploration opportunities benefit from having a nearby well calibration, such as seen in the Adi field; and this applies even in near-field exploration settings where geographical and geological variations are at play. However, where they exist, they should be used to calibrate our understanding of the subsurface and minimize depth uncertainty.

Due to the improved time-depth calibration of the subsurface, 2 contingent resource (CR) gas reservoirs were identified in the Adi field, which addresses the business drive to provide incremental volumes to the gas plant and enhance NING supply security.

In conclusion, the integration and understanding of geological and geophysical controls is critical for time-depth conversion, multi-discipline data integration and robust subsurface evaluation. Applying the right scaled methodology and understanding the impact of the chosen approach is critical to achieving business value.

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