NAPE/NAICE - 2019 | Lagos, Nigeria | 17-21 November 2019 | Abstract

Optimizing Hydrocarbon Recovery & Reducing In-Place Volume Uncertainty with Integration of PSDM (Reprocessed 1992 Vintage Seismic Data-set)

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ABSTRACT

The “XBOX” field is located in the OML-X block in the central part of the Onshore Niger Delta, Nigeria. This field was discovered in 1966 and production started in 1999 (currently recovery of 44% HCIIP from 14 producer wells). “XBOX” field has a total of 10 hydrocarbon-bearing levels situated between 2,850 and 4,100 m/MSL. The dynamic connected volumes (derived from P/Z & Cole Plots), and production data from the “XBOX” field indicated the need for an improved static volume (2018 version static model). The main drivers for this improvement are:

- The new structural maps derived from 2016 PSDM seismic interpretation using a robust velocity model as against a simple polynomial function hitherto used;
- The integration of the post-2008 model wells (well-15 to well-20) increasing the facies representativeness and corresponding petro-physical properties.

The approach adopted for 2018 “XBOX” field study consists of seismic interpretation, revised sedimentological interpretation, geological synthesis, reservoir synthesis, geo-modelling of reservoirs, subsequent review of GIIP and evaluation of the associated uncertainty.

The resulting model improved the match between static and dynamic Gas-In-Place. The field static GIIP volumes increased by ~10% compared to the 2008 results. The study also narrowed the volumetric 1P to 3P range by 50% as well as highlighted the scope for infill wells. Furthermore, this work illustrates the need for continuous integration of static and dynamic data in the life-cycle of a field.

1. Introduction

The “XBOX” (figure-1) is a major Oil and Gas field located in OML-X within the central part of the Onshore Niger Delta. The OML-X is a joint-venture between NNPC (60%) and TEPNG (40%, operator). “XBOX” was discovered in 1966 by well “XBOX”-1. It is formed of the Upper Oligocene (Rupelian to Chattian) deltaic sand deposits in depths ranging from -2850 to -4100 m ss (figure-2). The ten hydrocarbon-bearing reservoirs (namely levels 1 to 10) are structured along a ENE – WSW axis. This field is producing since Q4/1999. There are currently 20 wells on the “XBOX” structure.

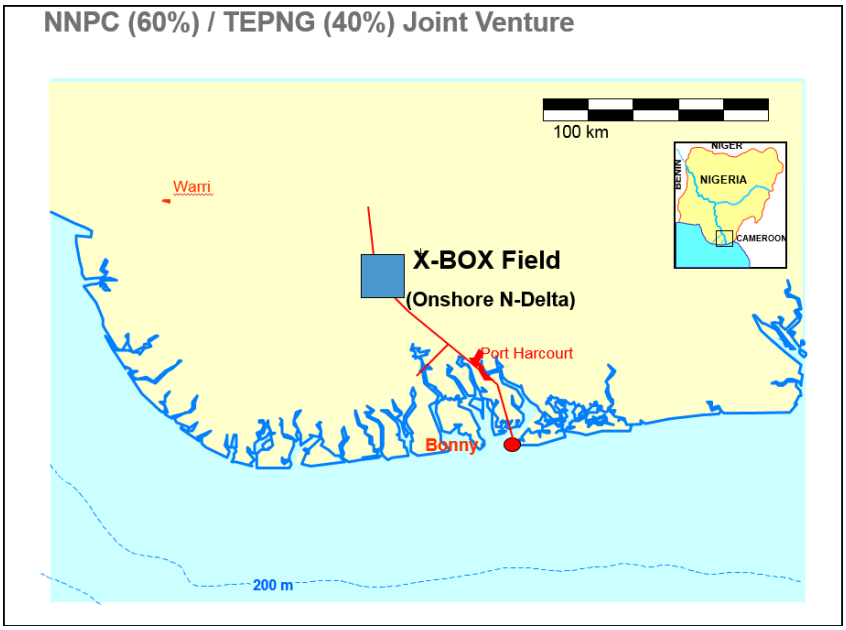

Figure-1: Showing “XBOX” Field Location

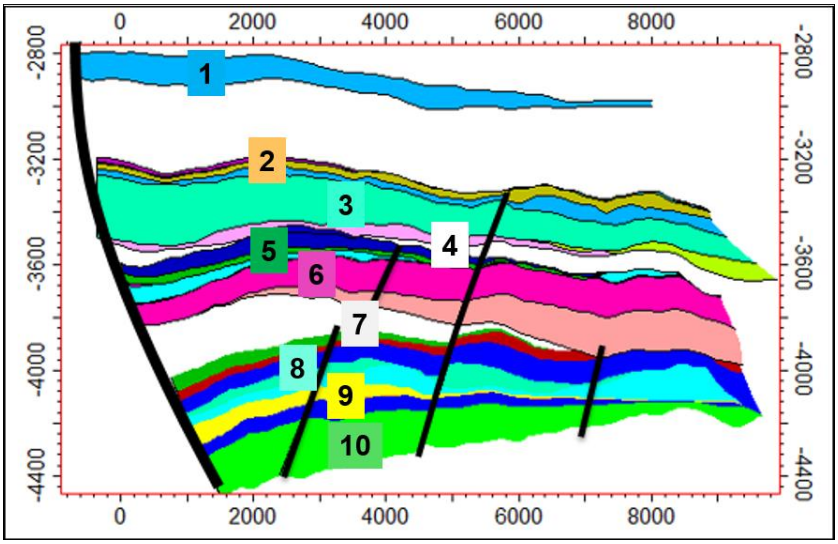

Figure-2: Geological cross section showing the 10 hydrocarbon bearing levels in “XBOX” Field.

The objective of this study is to revisit the static and dynamic evaluation of reservoirs 1 to 10 after the recent merged seismic data reprocessing (2016 PSDM) and the post-2008 model additional wells, to update the GIIP, reconcile the static and dynamic disparities and to serve as input to reservoir management including complementary development and well workovers.

This study takes into account the production history and the monitoring data as the field has been produced since 1999 and up to the end of 2018. This report includes the seismic and structural interpretation, the static and dynamic syntheses, the construction of the geological models and the HCIIP estimate. The study built up on existing interpretations and evaluations, especially the last field static and/or dynamic evaluation. HCIIP are compared to the last published figures from the 2008 static model report

- **Geological Settings**

The OML-X and in-block “XBOX” field lie within the emerged part of the Niger delta along the southern boundary of the Oligocene to Lower Miocene “Greater Ughelli” depobelt. During that period, the Niger paleodelta prograded on the shelf as a ”shelf delta” in a depobelt controlled by anastomosed systems of listric faults with weak throws associated with a weak depositional slope.

The “XBOX” sediments (dated from Oligocene) are characteristic of two main kinds of deltaic depositional systems:

- fluvial dominated deltas (Level-1 reservoir)
- Tidal / Fluvial dominated deltas (Level-2 to 10 reservoirs).

2. “XBOX” Study Inputs

- **Seismic data**

PSDM 3D Merged-survey seismic datasets stretched to Time were used to conduct the interpretation over the “XBOX” Field: This data was processed by a local (Nigerian) contractor in 2016-2017 using a robust angle design that produced better substacks

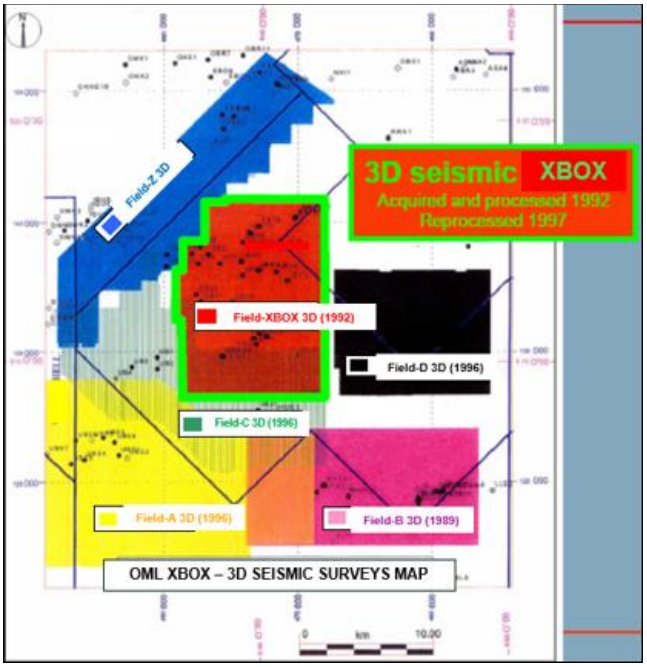

Figure-3: OML-X 3D Seismic survey map

- **3D "XBOX" Seismic Dataset Quality Control**

Acquired in 1992 by SSL and first processed in 1994, was reprocessed (Kirchhoff PreSTM) in 2002. In-house quality controls have shown that the 2002 PSTM processing was not optimum, therefore an in-house reprocessing has been conducted in 2006, including a 3D Deltastack®. The final 2006 dataset showed a good to fair seismic quality, improved fault definition and continuities are enhanced compared to the 2002 processing , but frequency bandwidth still remain low with a mean around 27 Hz.

The drawback of the 2006 dataset is its limited extension to the East which does not allow to fully image the eastern closure of some of the reservoirs and low amplitude preservation. This 3D dataset is, in its 2006 processing version, considered as the reference dataset over the "XBOX" field.

Due to improvement in technology and the absence of Velocity cube since the existence of the OML-X 3D data, PSTM reprocessing was attempted in 2011 and 2014 respectively. Both processing were inconclusive due to unreliable velocity cube. However, static corrections was applied but the spectral whitening applied destroyed the amplitude preservation.

PSDM processing launched in 2014 gave rise to a 7-survey merge processed cube in 2016-2017 which has a better velocity model, wider spectrum and improved resolution and better imaging of the faults. Amplitudes were better preserved compared to 2006 and 2011/2014.

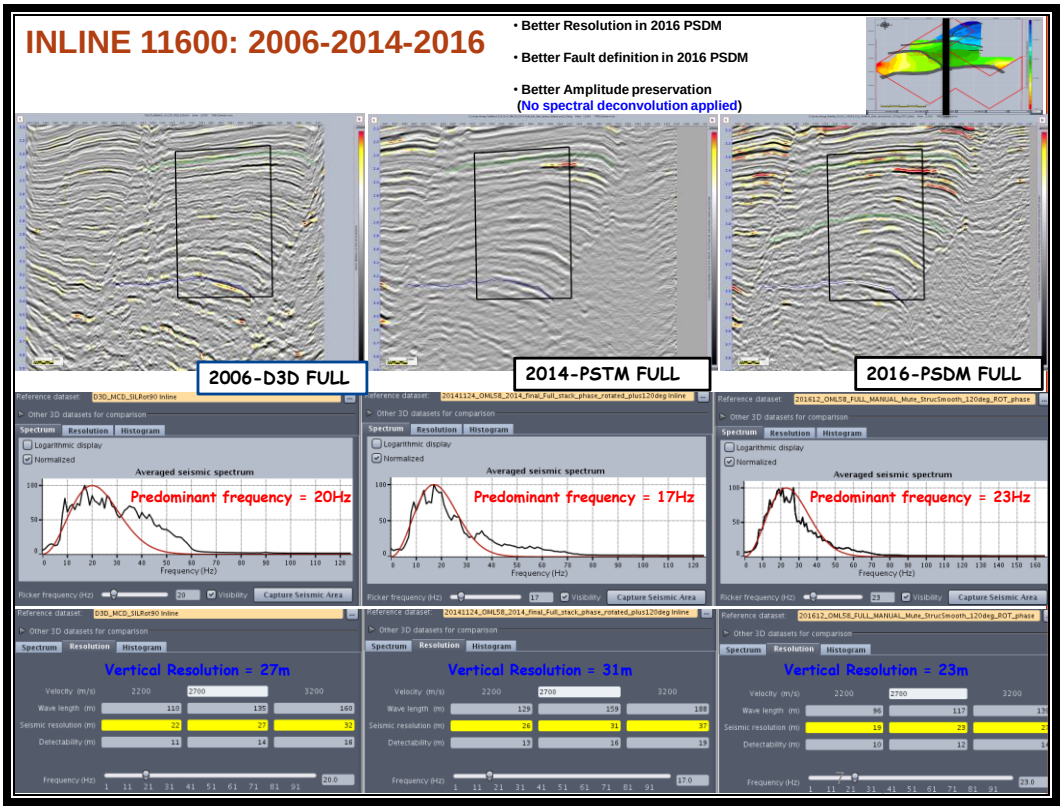

Figure-4: Predominant Frequency comparison between 2006, 2014 and 2016

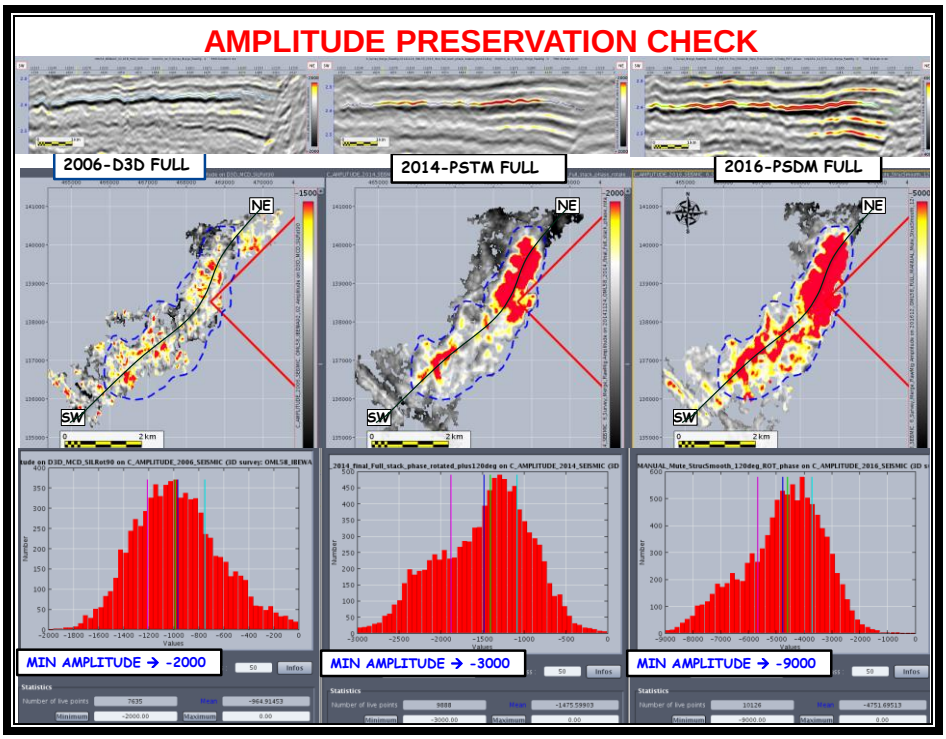

Figure-5: Amplitude preservation comparison between 2006, 2014 and 2016

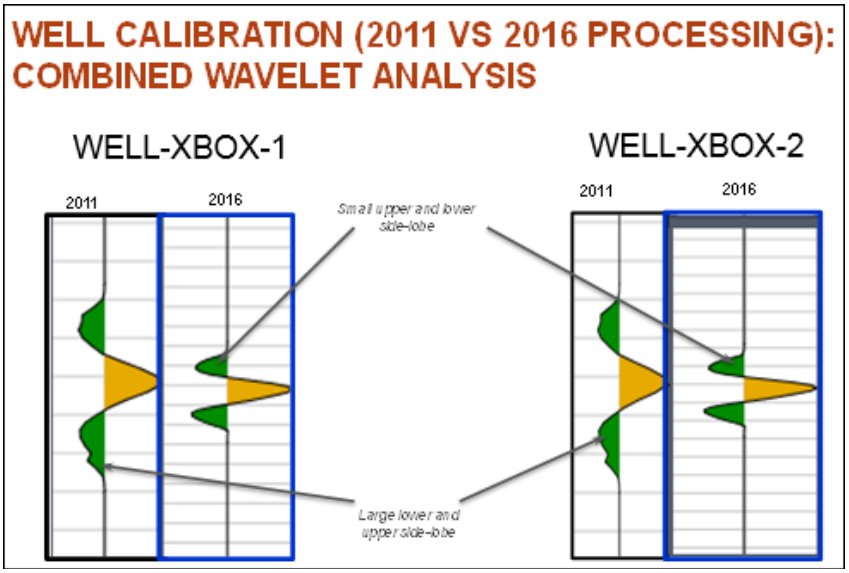

Figure-6: wavelet comparison between 2011/2014 and 2016

- **Well Data**

There is a total of 20 wells available in the study project database. The following table presents the whole set of available well log data. Among the 20 wells drilled over the "XBOX" field, few have reached reservoirs from 1 to 10 and have relevant data needed to perform well to seismic tie. 3 vertical and 2 deviated wells, geographically well spread over the "XBOX" field, have been used to perform seismic calibration.

WELL DATA XBOX-1 to 20 Wells	1	2	3	4	5	6	7	8	9	10
GR	20	19	17	17	18	17	16	16	13	6
RESISTIVITY	20	19	17	17	18	17	16	16	13	6
SONIC	10	13	12	14	14	14	14	14	11	4
DENSITY	14	13	14	11	13	13	14	14	11	5
NEUTRON	15	16	17	15	16	15	15	15	12	5
CHECK-SHOT / VSP	YES									
WFT	YES									
PVT	YES									
DST	NO	NO	NO	NO	YES	YES	NO	YES	YES	YES
CORES	YES	NO	NO	NO	YES	YES	YES	YES	YES	NO
20 Number of Spatial Representiveness										

Figure-7: Available log data from "XBOX" ("XBOX"-01 to "XBOX"-20) wells

- **Core Data**

There are 493 meters of cores from “XBOX” wells covering all reservoirs except Level-2, 3 & 4.

These cores were used for the 2018 model sedimentological review. Plugs were cut and the following core measurements are available:

- 227 X-ray diffraction;
- 1601 conventional Phi – K – Rhos measurements;
- 137 Capillary Pressure experiments (39 Purcell, 74 Porous Plates and 12 centrifugations).

- **Tests Data**

A total of 11 well tests were performed in the “XBOX” appraisal wells. These tests were motivated by the recovery of a valid reservoir fluid sample as the economy of the field is dependent on the content in condensate (CGR).

These tests are valid by themselves, with generally long build-up. However pressure recordings are sometimes of low quality. Eight tests were interpreted; the three others cannot be interpreted due to data quality.

- **Production Data**

Production started in November 1999. Wells are producing both gas and condensate. The condensate rate peaked at 19 KBOPD in December 2000. The present-time production at mid-2018 are 10 KBOPD condensate and 7.6 MMSm3 gas as per end of 2018.

3. Geosciences and Reservoir Interpretations/Findings

- **Seismic data**

The 10 time horizons realized from the seismic interpretations are in four packages; level-1 as in standalone package, Levels-2-3-4 as 3 levels in one package, levels-5-6-8 and levels-8-9-10.

The time horizons were converted to depth maps using several Time-Depth conversion methodologies: Generalized polynomial law, Coefficient polynomial function and PSDM velocity model. The base case is the velocity model obtained from the PSDM processing.

This has an advantage of correcting for lateral velocity variations. The second is the Coefficient Polynomial derived from “XBOX” wells with check shots as well as complete and reliable well calibration log suite (Compressional sonic, Density, Caliper, Resistivity, Neutron and Gamma ray logs) by creating krigged map of coefficient “b” and “c” maps. This coefficient polynomial law was used to depth-convert the structural maps of 2006 for the 2008 model building. It was also tested on the 2016/2017 PSDM structural maps for comparison purposes.

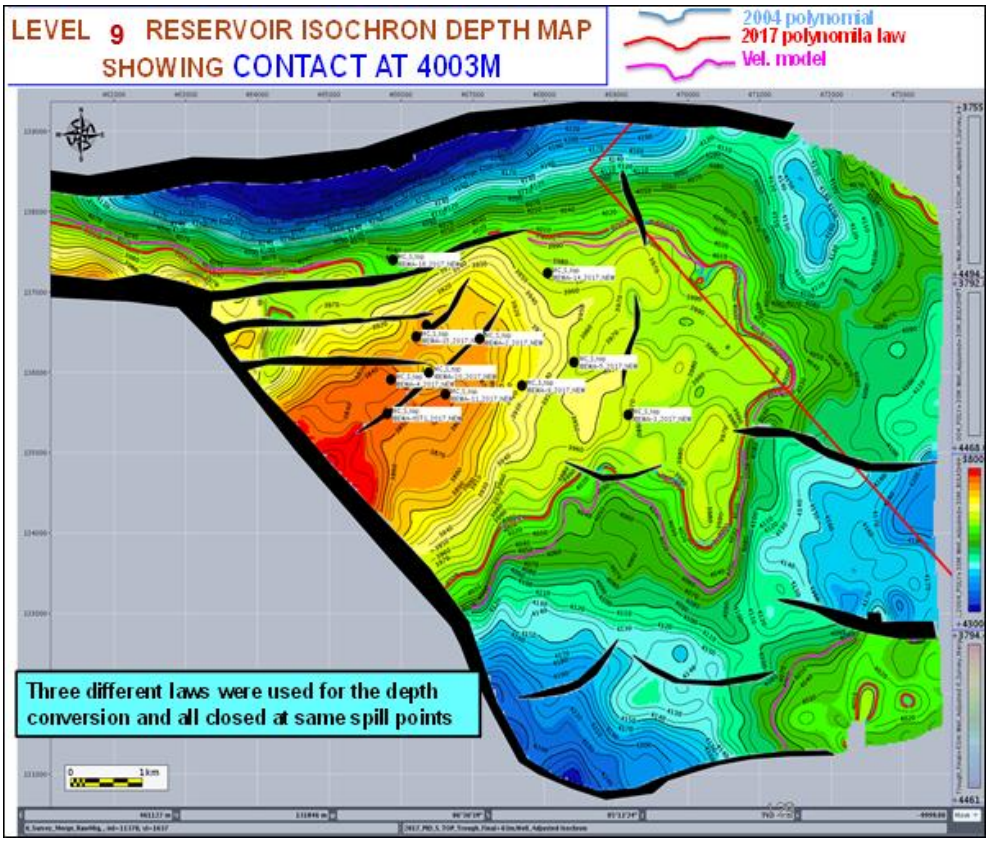

Figure-8: Depth Map Overlaid with Contacts from different Depth Conversion Laws.

For the seismic interpretation, the time to depth conversion methodology used plays a very important role on the GRV computation. A quick analysis done to compare the results obtained with the two polynomial models shows that the coefficient polynomial law, as was done in 2008, could not account for the lateral velocity variation in the absence of the proper velocity model; it however, penalised the GRV. Same 2016 PSDM velocity law was applied to the isochron maps of 2008 and 2016 maps at different levels to convert to depth (figure-9), it shows that the result are almost close and better than the coefficient Polynomial.

COMPARISON BETWEEN 2016 PSDM AND 2008 COEFFICIENT POLYNOMIAL LAW APPLIED TO BOTH 2008 AND 2016 INTERPRETATIONS.

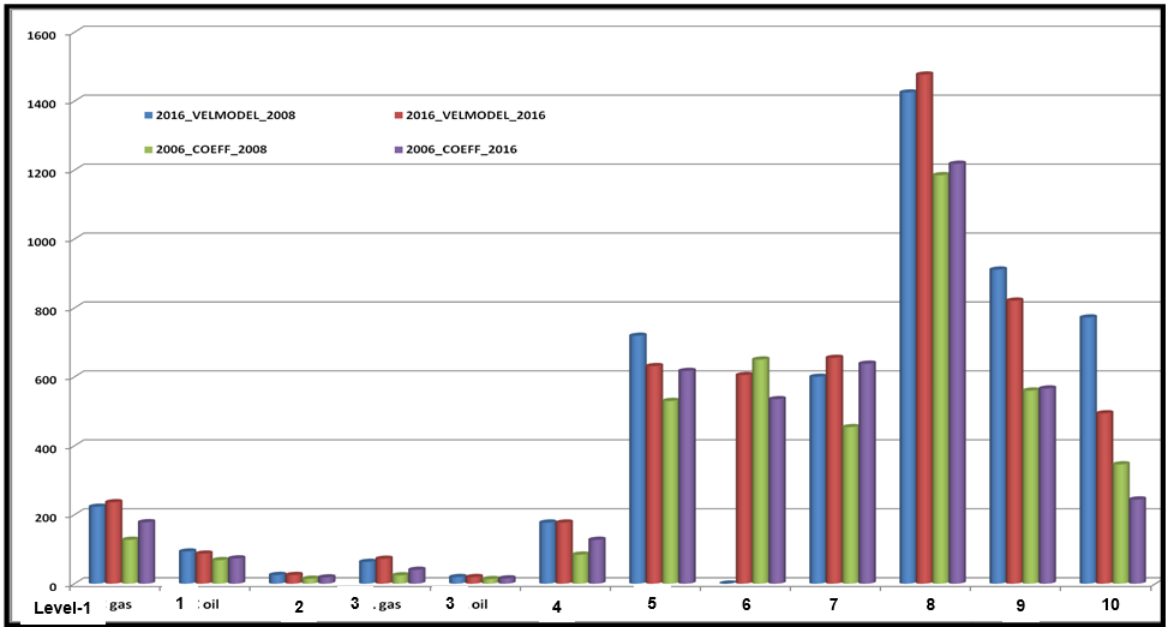

Figure-9: GRV Computation from different Depth Conversion Laws.

- **Sedimentary Synthesis**

This quick-look sedimentary synthesis was done, the objective was to review the sedimentary model of the "XBOX" reservoirs 1 to 10, by reviewing the existing core interpretation and depositional environments.

CORE INTERPRETATION (2000 vs 2008 vs 2018)

LEVELS	2000	Source	2008	Source	2018	Source
Level-1	Wave-dominated	LOGS	Fluvio-deltaic	CORE	Fluvio-estuarine	CORE
Level-2	Transgressive (Fluvial-dominated)	LOGS	Wave-dominated (shoreface)	LOGS	Tide & fluvial-dominated	LOGS
Level-3	Fluvial-dominated	LOGS	Wave-dominated (shoreface)	LOGS	Tide & fluvial-dominated	LOGS
Level-4	Fluvial-dominated	LOGS	Wave-dominated (shoreface)	LOGS	Tide & fluvial-dominated	LOGS
Level-5	Tide-dominated & some wave-reworking	LOGS	Wave-dominated (shoreface)	CORE	Predominantly tidal & fluvial facies (channels, tidal channels and tidal bars)	CORE
Level-6	Tide-dominated & some wave-reworking	CORE	Wave-dominated (shoreface)	CORE	Predominantly tidal & fluvial facies (channels, tidal channels and tidal bars) with some wave reworking	CORE
Level-7	Tide-dominated & some wave-reworking	LOGS	Wave-dominated (shoreface)	CORE	Predominantly fluvial & tidal facies (channels, tidal channels and tidal bars).	CORE
Level-8	Tide & fluvial-dominated	CORE	Wave-dominated (shoreface)	CORE	Predominantly tidal & fluvial facies (fluvial/tidal channels, tidal bars)	CORE
Level-9	Tide & fluvial-dominated	CORE	Wave-dominated (shoreface)	CORE	Predominantly tidal & fluvial facies (fluvial/tidal channels, tidal bars)	CORE
Level-10	Fluvial & tide-dominated	LOGS	Wave-dominated (shoreface)	LOGS	Predominantly tidal & fluvial facies (fluvial/tidal channels, tidal bars)	LOGS

Figure-10: "XBOX" Core Interpretation (2000 vs 2008 vs 2018)

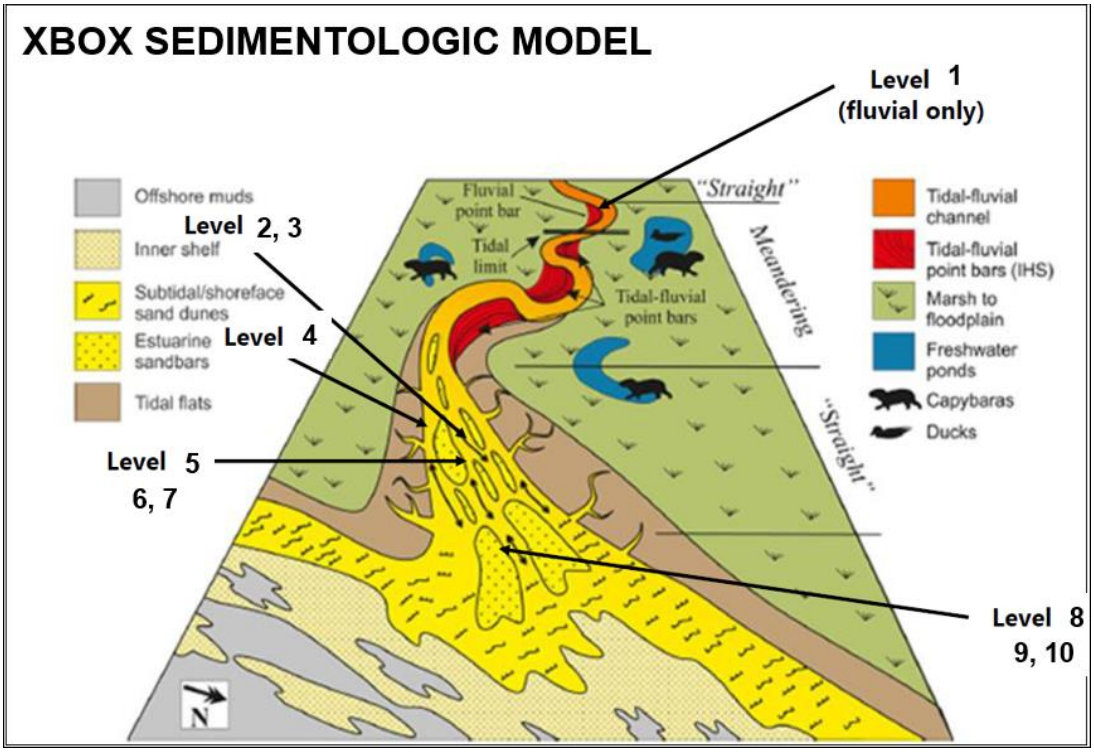

Figure-11: "XBOX" Sedimentological Model (2018)

There are two major kinds of depositional systems identified in the "XBOX" field:

1. A tide/fluvial dominated delta characterized mainly by aggrading and coarsening-upwards parasequences in Levels 10 to 2.
2. Fluvio-estuarine dominated environment in Level-1.

Petro-physical Synthesis

The 6 Static Rock Type (SRT) corresponds to:

1. Shale
2. Cemented zone
3. Silty shale with bioturbation, loading with occasional diagenetic nodules
4. Laminated silty shale
5. Laminated fine sandstone
6. Clean fine to coarse sandstone

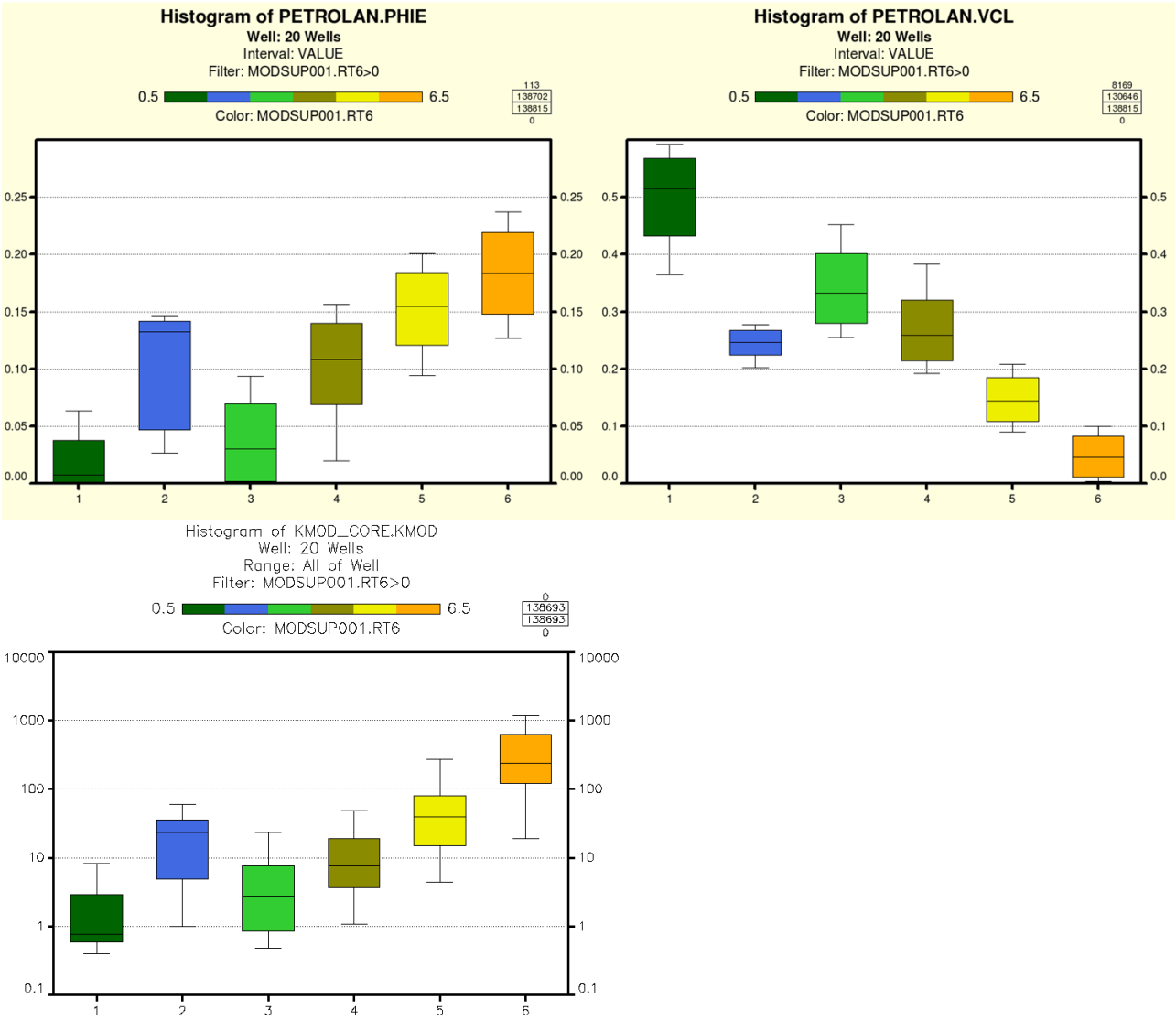

Figure-12: The six (6) EF, histograms of PHIE, VCL & PERM (K_MOD)

The proposed cut-off excluding non-contributing facies are as follows:

- PHIE >= 5%
- VCL <= 35%
- Kmod >= 1mD

According to static fluid contact criteria observed in log data, reservoirs were grouped into two categories or configurations:

a. Levels without any indication of compartmentalisation: levels 1, 2, 3, 5 & 6.
b. Levels with significant (10 meters or more) differences in initial fluid contacts among wells; this is the case in levels 4, 7, 8, 9 & 10. These levels are considered as compartmentalized; all are gas bearing. Their GWC is discussed in the review by level hereafter.

4. "XBOX" 2018 Static Model Result & Comparison with 2008 Model

The 2018 "XBOX" Static Model is the most up to date representation of the field geology incorporating the 6 post-2008 "XBOX" wells and the most recently reprocessed seismic (PSDM 2016).

The time to depth conversion methodology used (polynomial in 2008 versus velocity model in 2018) plays a very important role on the GRV computation. A quick analysis done comparing the laws shows that the coefficient polynomial law made attempt to account for the lateral variation in the absence of the proper velocity model required in 2008, it however, penalized the GRV. Same 2016 PSDM velocity law was applied to the Isochron Maps of 2008 and 2016 maps at different levels to convert to depth, it shows that the result are almost close and better than the coefficient Polynomial.

Globally, the main uncertainty in order of magnitude are; **(1) PHIE_net (2) GRV, (3) Water Saturation & (4) Facies**. GRV is the key uncertain driver in this study main levels of interest (levels 1, 4, 7 & 10).

A Base Case GIIP of 76.3 "Giga Units", Low Case scenario of 63 "Giga Units" and High Case scenario of 86 "Giga Units" has been estimated for the Field. ***The wider 1P to high 3P cases volume range observed in the 2008 uncertainty study was reduced in the 2018 uncertainty results*** (**2008: 50 "Giga Units" to 102 "Giga Units"** range compared to **2018: 63 "Giga Units" to 86 "Giga Units"**). To further unlock more value from the "XBOX" field and entire OML-X, there is need to acquire 6km cable length seismic data.

With a global recovery factor of 40% and some levels indicating possible attic volume and/or disconnected accumulations; this issue which was part of the objective for this study, will be resolved with infill wells proposal and maturing.

2008 vs 2018 BC Comparison				Low Case Comparison			High Case Comparison		
Base Case GIIP ("Giga Units")				("Giga Units")			("Giga Units")		
Level	2008	2018	Diff (%)	2008	2018	Diff (%)	2008	2018	Diff (%)
1	3.5	5.2	48.6%	2.4	4.1	70.8%	4.9	6.2	26.5%
2	0.3	0.44	46.7%	0.2	0.2	0.0%	0.4	0.4	0.0%
3	1.2	2	66.7%	0.9	1.3	44.4%	1.8	2.1	16.7%
4	1.4	2.8	100.0%	1	2.6	160.0%	2.1	3.5	66.7%
5	8.6	9	4.7%	6.3	9	42.9%	12.2	13.9	13.9%
6	17.2	17.2	0.0%	13.5	15	11.1%	28.3	19.3	-31.8%
7	9.2	10.8	17.4%	6.9	8.7	26.1%	15.1	11.4	-24.5%
8	10.6	13.85	30.7%	8	9.6	20.0%	13.8	13.85	0.4%
9	13.3	11.6	-12.8%	9	9.3	3.3%	18.6	12.32	-33.8%
10	3.1	3.4	9.7%	1.8	2.7	50.0%	4.6	4	-13.0%
Total	68.4	76.29	11.5%	50	62.5	25.0%	101.8	86.97	-14.6%

Table-1 – "XBOX" 2018 GIIP (Base / Low / High) cases with comparison to "XBOX" 2008

Acknowledgements

The authors would like to thank the managements of TEPNG, NAPIMS and DPR for their support to the case of study and the Asset JV Geosciences activities. We also thank NAPE for the opportunity to share this study case at NAPE 2019 conference. The statements made in this extended abstract represent the views expressed by the authors and not necessarily the views held by their employer(s) above.