Using High Fidelity OBN Seismic Data to Unlock Conventional Near Field Exploration Prospectivity in Nigeria's Shallow Water Offshore Depobelt.

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ABSTRACT

It is well-established that Nigeria's Shallow Water Offshore depobelt has large exploration potential and provides an upside for long term hydrocarbon production security. Long-standing imaging challenges associated with legacy streamer seismic data have led to safe and efficient acquisition of high-fidelity Ocean Bottom Node (OBN) seismic data covering three Oil Mining Leases' (OML's) in the Depobelt. Multiple processed vintages of the data have resulted in better illumination of the subsurface structural and stratigraphic framework. This paper focuses on how the OBN data has helped improve our evaluation of the SOMA prospect.

SOMA is an amplitude supported, 2-way fault bounded footwall closure bordered by key analogue wells to the north and south of the opportunity. The objective interval spans Pliocene to Messinian Upper plays with a depth range of 2,000 to 9,000ft (within the hydrostatic and amplitude domain). Compared to the legacy data, the new OBN data highlights a minor late-stage fault that compartmentalizes the prospective block separating it into two compartments – Block A & Block B. Eleven Reservoir Seal Pairs (RSP's) were interpreted and risked as gas. However, only three of the RSP's were considered commercially viable – contributing 56% of the entire prospect's Ultimate Recovery (UR). The reservoirs are expected to be mostly channels (single/multi-storey) and shorefaces deposited in the inner to outer shelf environment.

Observed Direct Hydrocarbon Indicators (DHI's) show good calibration with offset wells where amplitudes conform to structure, are consistently higher in hydrocarbon filled sands and switches off in the brine leg. This paper aims to share key observations, results & learnings deduced from adopting an integrated subsurface approach, with strong subsurface collaboration geared towards delivering drill ready Near Field Exploration (NFE) volumes to support the business.

Keywords: Near Field Exploration, Ocean Bottom Node, Reservoir Seal Pair, Direct Hydrocarbon Indicator.

INTRODUCTION

The prospective area of interest is in the Niger Delta's Shallow Water Offshore (SWO) depobelt (Figure 1). Numerous articles exist on the evolution and tectono-stratigraphic history of the Niger-Delta, good examples include works by Short and Stauble, 1967; Avbobvo, 1978; Doust and Omatsola, 1990; Kulke, 1995, Haack et al., 1997 and Tuttle et al., 1999. SOMA is a structural footwall trap with objective reservoirs that sit within the hydrostatic domain well above the amplitude floor. Proper definition of the geological model integrating seismic facies analysis, stratigraphic framework & acoustic impedance volumes helped reduce our uncertainty around reservoir presence and continuity.

Near field exploration effort is heavily dependent on the seismic data available. It's quality therefore is of utmost importance as it can influence the interpretation put forward by the subsurface evaluation team. Nigeria's shallow water offshore depobelt has been the focus of recent gas exploration seeking to fill Nigeria Liquefied Natural Gas (NLNG) Train seven. This supported the decision to acquire high fidelity seismic data using Ocean Bottom Node (OBN) technology. Our evaluation of the subsurface using the recent data has emphasized the benefits of OBN seismic acquisition which has been well documented by Bjorn O., 2011; Hou K., 2018 and Frømyr E., 2020.

The SOMA lead was originally identified on legacy streamer seismic data which was of sub-optimal quality to adequately reduce uncertainties around structural definition (Figure 2) and mature the lead to a prospect. In this paper we highlight the impact of using OBN seismic data to mature this amplitude supported opportunity from an exploration lead to prospect.

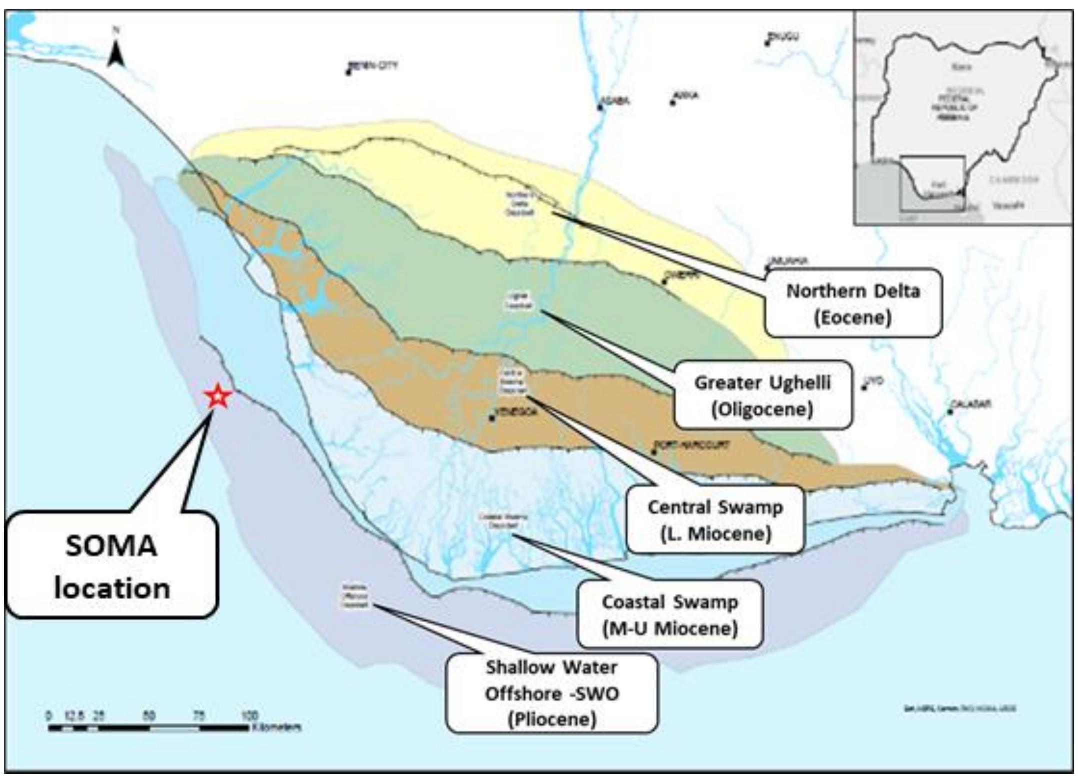


Figure 1: *Map of the Niger Delta Showing the Depobelts (emphasis on the Shallow Water Offshore Depobelt).*

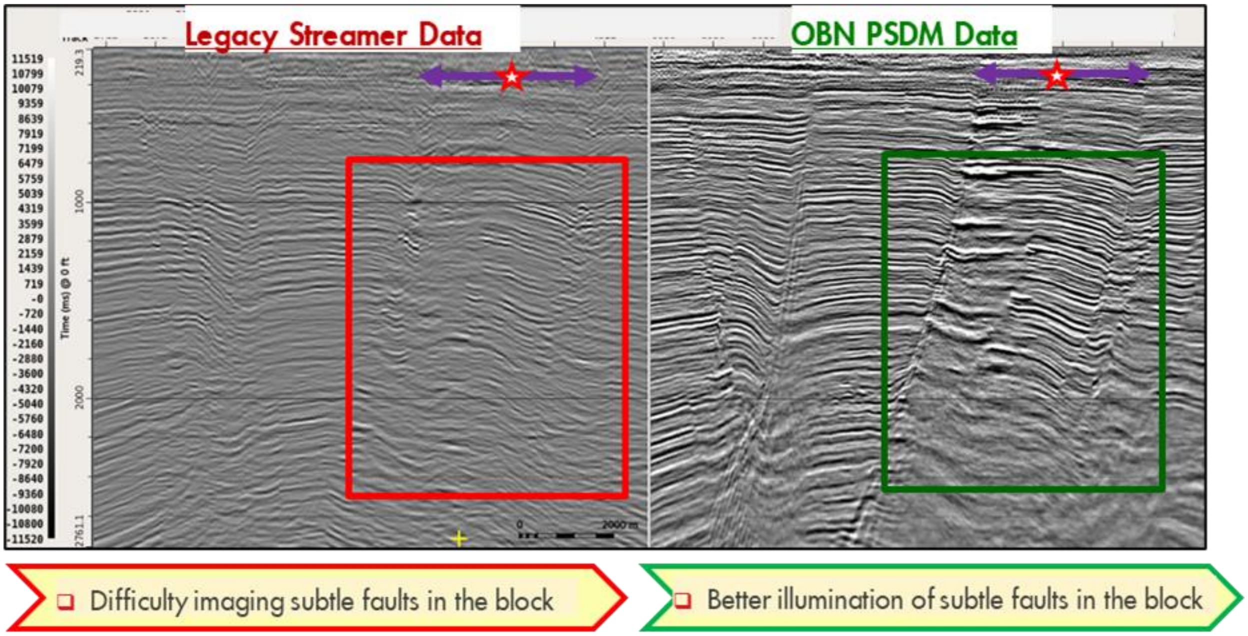


Figure 2: *Seismic data comparison highlighting improved fault resolution and loop continuity in the OBN data.*

Objectives & Business Drivers

SOMA provides gas backfill opportunity to support Nigeria Liquefied Natural Gas train seven (NLNG T7) leveraging newly acquired OBN seismic data. Compared to other shallow water offshore deep prospects, this opportunity has good competitive well cost given that target reservoirs are located within the hydrostatic depth window.

METHODOLOGY

Integrated Workflow: The methodology adopted for this evaluation leveraged an integrated approach (Figure 3) to unravel the subsurface structural & stratigraphic framework and help reduce uncertainties around reservoir presence/continuity, structural definition and column length estimation for volumetics analysis.

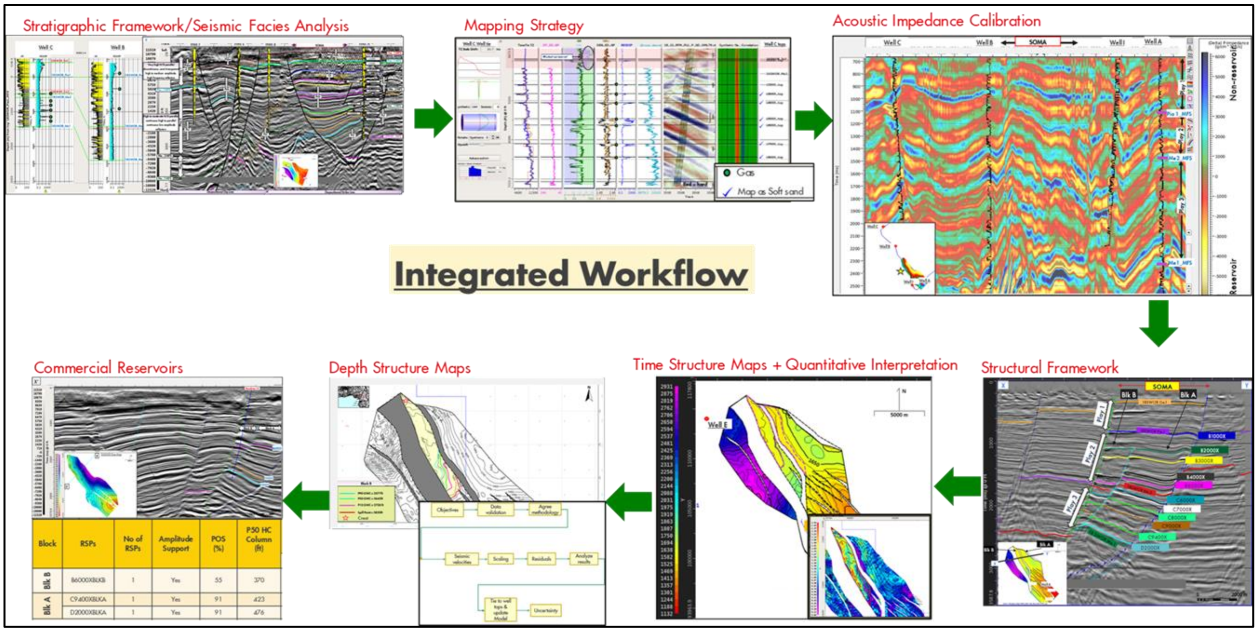


Figure 3: *Integrated workflow adopted for the evaluation.*

Sub-regional correlation was done intergrating petrophysical well logs and regional biostratigraphic marker tops from seven (7) wells penetrating Tortonian 2, Messinian 1, Messinian 2 and Piacenzian 1 3rd order maximum flooding surface's (MFS), to generate a framework of stratigraphic plays. The key plays of interest are Play 2 (defined at the top by Piacenzian 1 and bounded at the base by Messinian 2 MFS) and Play 3 (defined at the top by Messinian 2 and bounded at the base by Messinian 1 MFS). Seismic facies analysis coupled with petrophysical well logs proved very effective to establish the environment of deposition (EOD) as inner shelf (in Play 2) and mid to outer shelf (in Play 3). Acoustic impedance volume was generated to qualitaively assess reservoir continuity from the analogue well (Well A) to the prospective block.

Leveraging semblance time slices generated from high fidelity OBN data, detailed structural interpretation was carried out to properly define the propspective block of interest. In plan view, the semblance slices were useful in highlighting discontinuity trends and aiding with quality assurance (QA) & quality control (QC). The mapping strategy was defined based on robust seismic to well ties achieved for two of the key wells in the study area (reservoir tops are interpreted as soft loops). Hydrocarbon bearing reservoirs in the analogue well were correlated directly into the prospect block, strong positive amplitudes within the block were also mapped as potential hydrocarbon bearing resevoirs.

A total of eleven reservoirs were consistently mapped, honouring expected throw profile of the late stage compartmentalizing fault that splits the reservoir seal pairs into two separate blocks (Blocks A&B) as shown in Figure 7. The resultant two-way time (TWT) structure maps were depth converted to create a couple of structural depth maps (Fighure 9). Amplitude extraction was carried out for the mapped reservoirs to help reduce uncertainties around column height estimation and to help polarise the prospect Possibility of Success (PoS).

RESULTS AND DISCUSSION

The summary of the results from our subsurface evaluation using the recent OBN seismic data are presented in Figures 4 to 13 below.

Figures 4 to 6 show evidence of good reservoir presence and quality in the prospect area of interest. Expected reservoirs in play's 2 and 3 have been tested by the analogue well (Well A) and it was possible to establish correlation into the SOMA block using the acoustic impedance volume. Seismo-sequence stratigraphic analysis demonstrates that reservoirs are expected to be mostly channels (single/multi-storey) and shorefaces deposited in the inner to outer shelf environment.

Figures 7 & 12 clearly demonstrate the improvement in quality of the OBN seismic data (compared to the legacy streamer data), which alllowed for proper characterisation of the trapping configuration (2-way fault bounded footwall closure) of the SOMA block. We clearly see the effect of a late stage synthetic fault that compartmentalizes the block into two (Blocks A&B). The OBN data proved to be the main interpretation game changer from what was put forward in previous interpretation effort in the area.

Figures 8 & 9 show three representative (out of the eleven mapped) two-way time and depth structure maps respectively. Quantitative interpretation (QI) was carried out on all the interpreted reservoirs after achieving good amplitude calibration with logged hydrocarbon water contact at D5000 reservoir, tested by our analogue well (Well A) – this positive calibration (Figure 13) increased our confidence in the subsequent QI results. The results (Figure 10) show good amplitude fidelity across target reservoirs with stable conformance to structure and amplitude switch off shallower than expected spill point depth. This analysis supported the team with hydrocarbon column height predictions necessary for volumetric estimation and PoS high-grade/down-grade.

Detailed volumetric analysis established three reservoirs (B6000X_Block B, C9400X_Block A & D2000X_Block A) to be commercial accounting for about 56% of the entire recoverable volumes with moderate to high PoS (Figure 11).

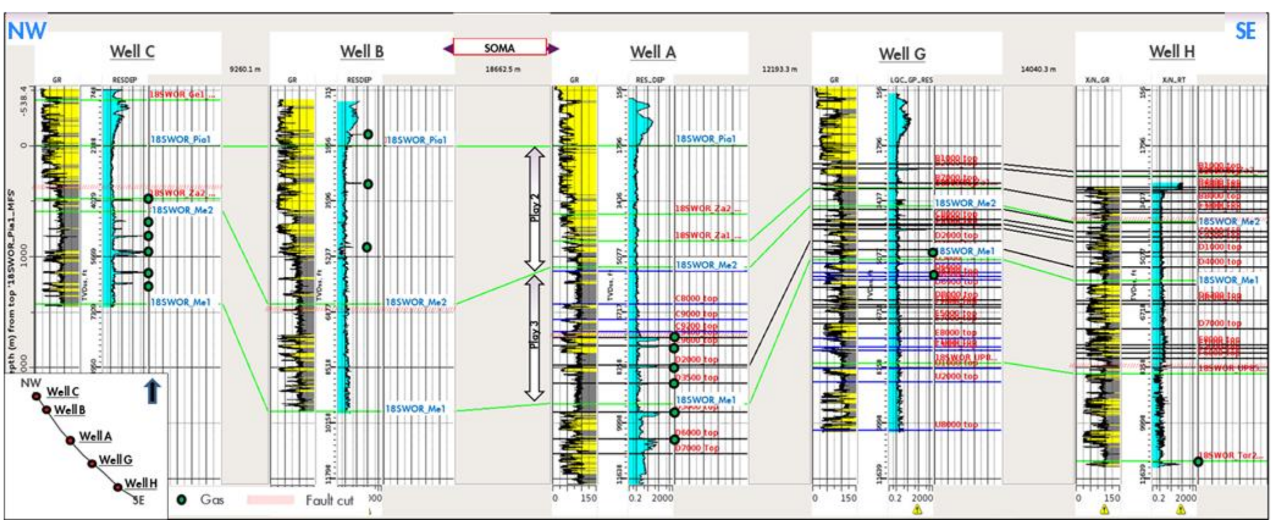
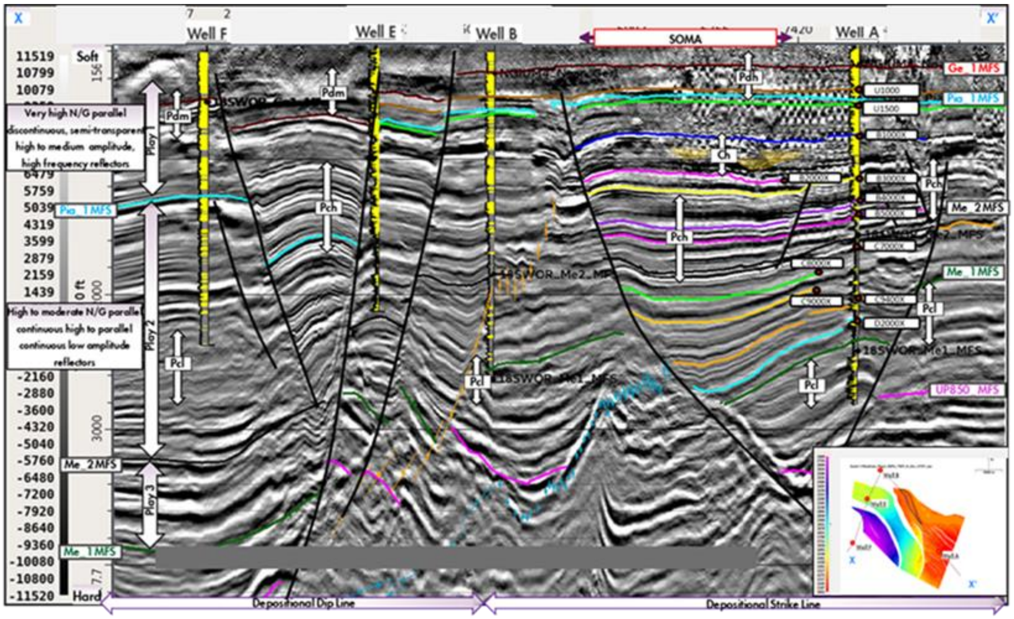


Figure 4: *Sub-regional correlation along depositional dip integrating key wells in the area.*



RSP Interval	Internal architecture	EOD/Facies Interp.	GDE (Play2/3)
UI000 – B6000X	Pdh, Ch, Pch	Coastal Plain to Inner Shelf: amalgamated channel complexes, shorefaces.	Lower Shelf
C7000X – D2000X	Pch, Pcl,	Mid to Outer Shelf: shoreface, Fluvial channels	

Seismic Facies Classification Scheme

Pch: Parallel Continuous High amplitude reflectors
Pcl: Parallel Continuous Low amplitude reflectors
Pdh: Parallel discontinuous high amplitude reflectors
Pdm: Parallel discontinuous medium amplitude reflectors
Ch: Base truncating low amplitude, chaotic, discontinuous reflectors

Figure 5: *Seismic section through wells with key stratigraphic markers (Gelasian 1 to Tortonian 2 maximum flooding surfaces).*

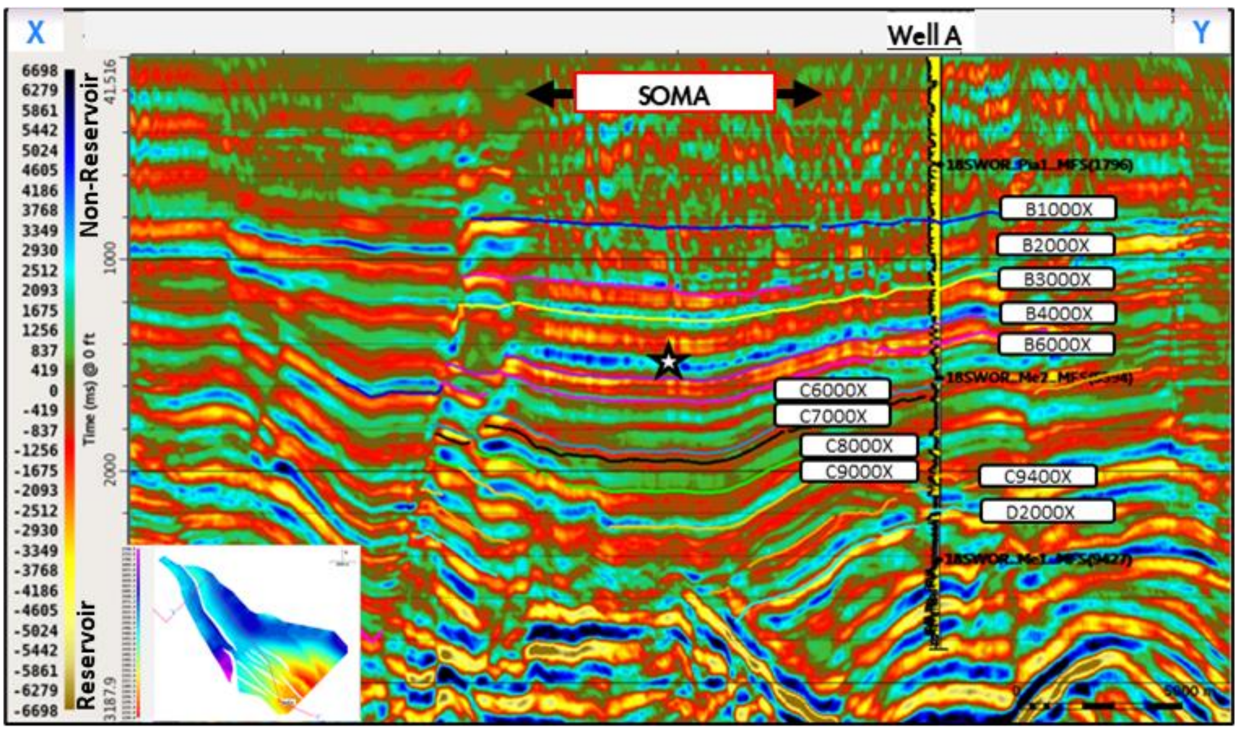


Figure 6: *Acoustic Impedance volume showing qualitative assessment of reservoir continuity from analogue well to prospect.*

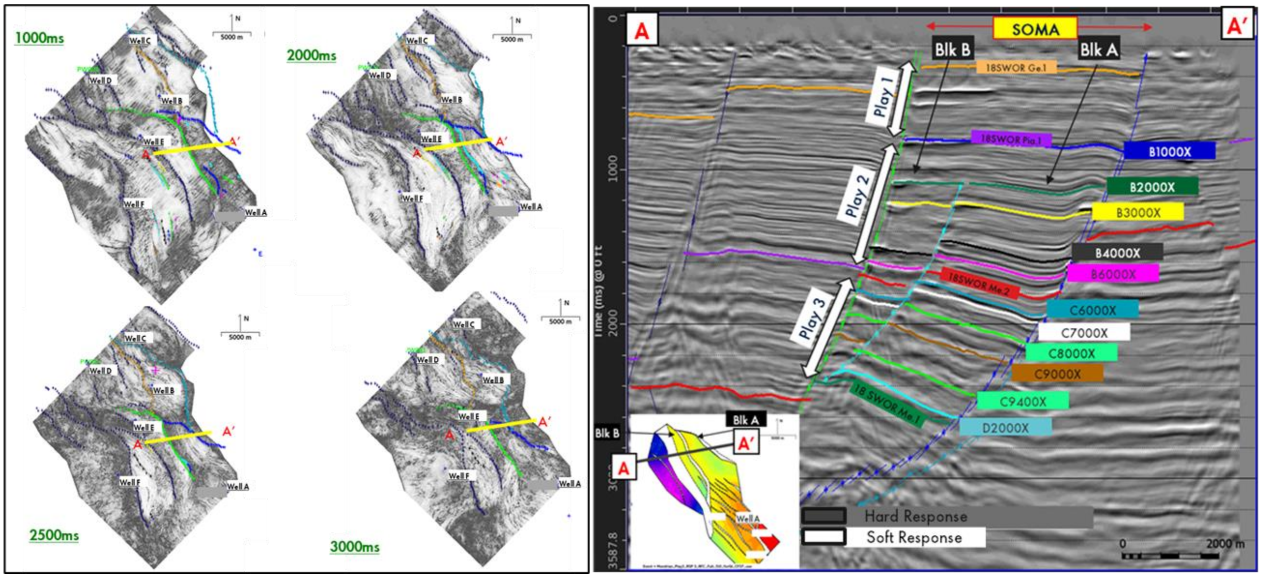


Figure 7: *Semblance time slices (1-3seconds) & seismic cross section displaying the structural trapping mechanism controlling reservoir deposition.*

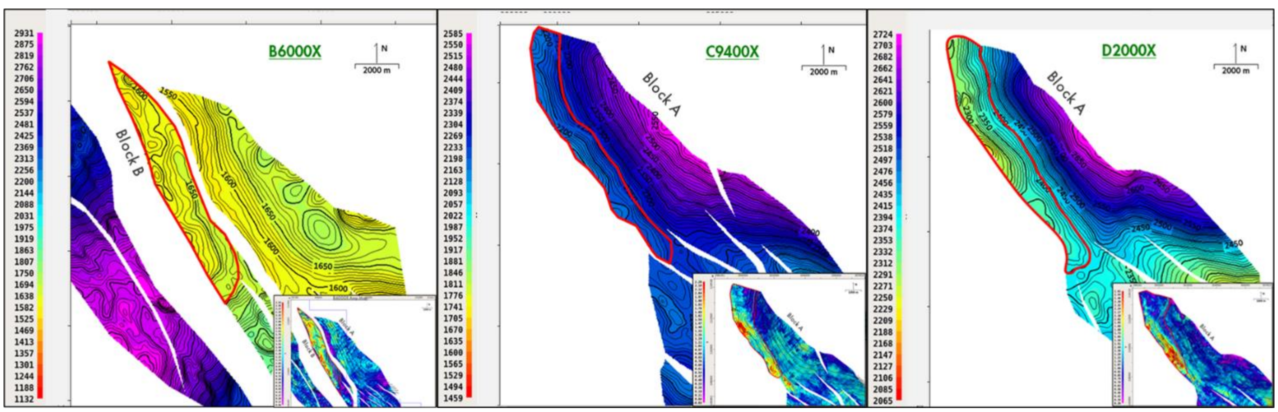


Figure 8: *Two-way time (TWT) structure maps for representative reservoir seal pairs.*

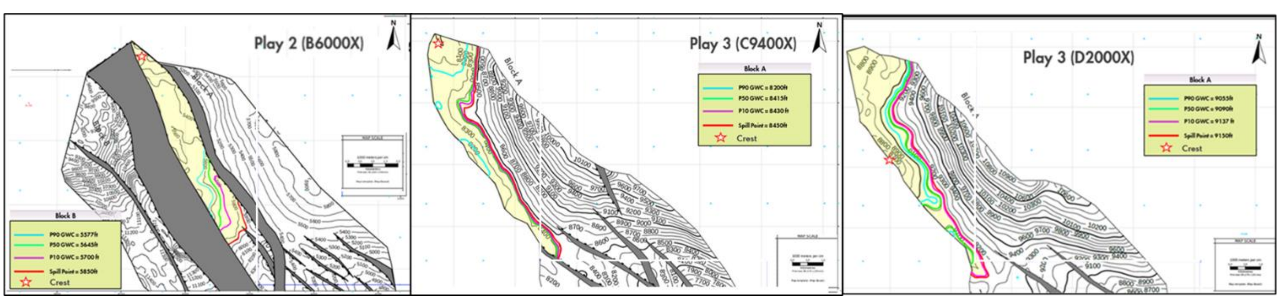


Figure 9: *Depth structure maps for representative reservoir seal pairs.*

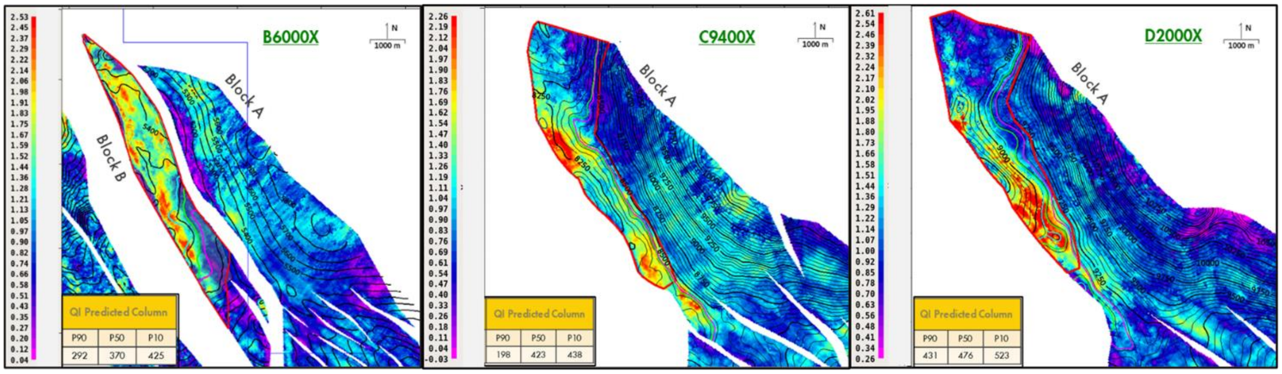
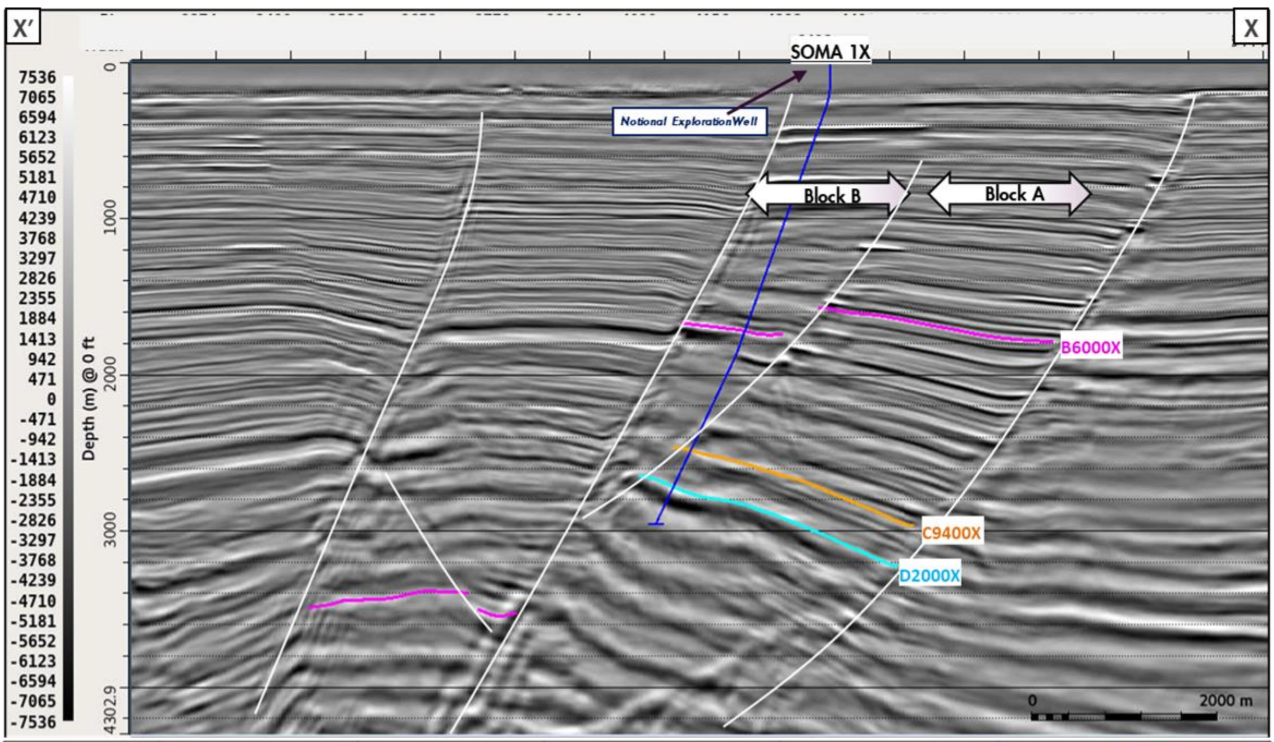


Figure 10: *Amplitude maps for representative reservoir seal pairs with depth contours displayed.*



Block	RSPs	No of RSPs	Amplitude Support	POS	P50 HC Column (ft)
Blk B	B6000XBLKB	1	Yes	Moderate	370
Blk A	C9400XBLKA	1	Yes	High	423
	D2000XBLKA	1	Yes	High	476

Figure 11: *Seismic section showing notional well traversing commercial reservoirs*

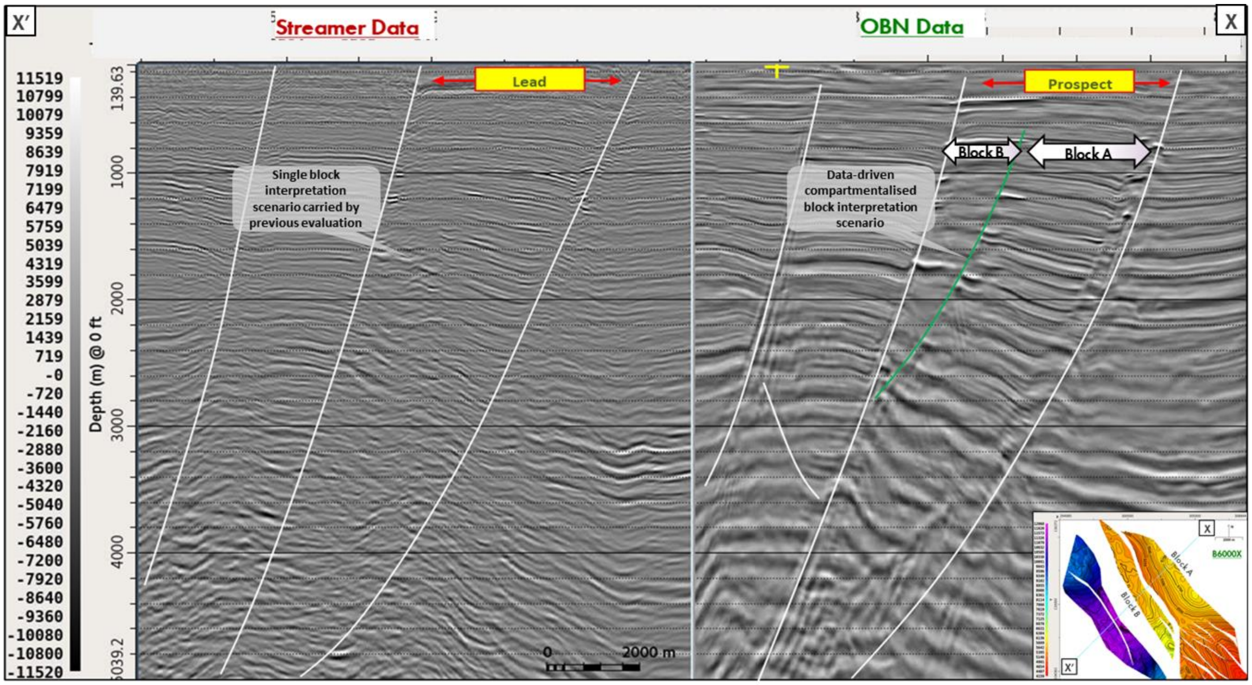


Figure 12: *Seismic section showing updated interpretation on the OBN seismic compared to the legacy streamer data.*

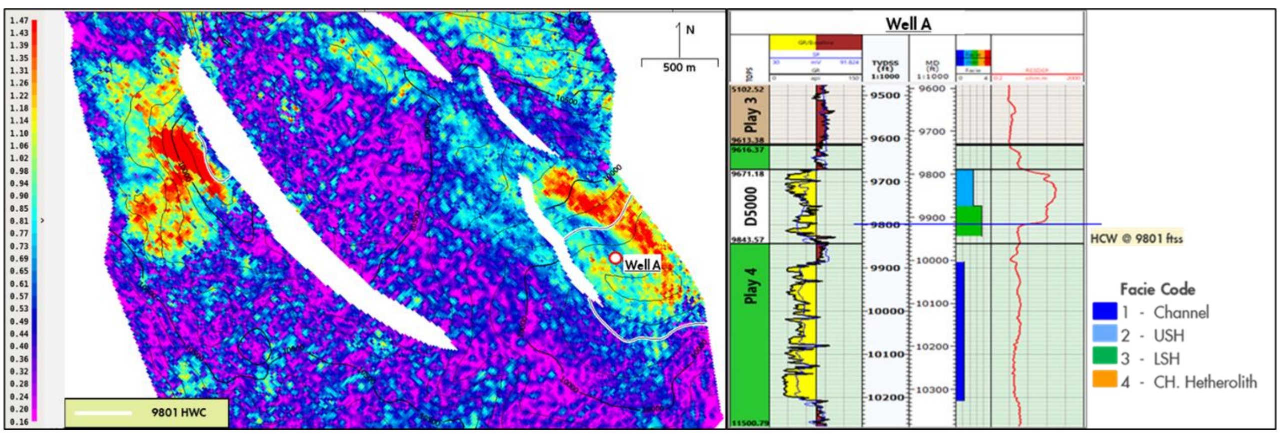


Figure 13: *D5000 amplitude map (tested by Well A) showing logged hydrocarbon water contact.*

CONCLUSIONS AND BUSINESS IMPACT

Overall, the new OBN data has proven to be an exploration gamechanger. Three key upsides of the data includes:

1. Better fault plane definition, especially the subtle compartmentalizing faults previously missed by legacy streamer data. The key impact of this is that it has reduced the structural imaging uncertainty carried in previous evaluations & has helped mature opportunity from lead to prospect.
2. Improved horizon resolution & lateral continuity which improved our ability to map target reservoirs from the analogue well into the prospective block with a high degree of confidence.

3. Improved stable amplitude preservation which supported DHI hunting and identification with direct implications on column height estimation & prospect PoS polarization.

These improvements in data quality helped the team de-risk three key elements of the petroleum play (reservoir, structure & seal). Leveraging this, the team unlocked significant exploration volumes – **94% volume increase** (nearly double the legacy volumes) compared to previous evaluation with legacy streamer seismic data.

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