Deep-Water Reservoir Potential in Frontier Basins Offshore Namibia Using Broadband 3D Seismic

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SUMMARY

The four offshore basins of Namibia are highly underexplored despite one of these basins containing the large undeveloped Kudu gas field. Substantial discoveries elsewhere on both sides of the South Atlantic conjugate margin have brought new focus on the potential of the entire West African margin. With billion barrel fields in neighbouring Angola to the north, attention has turned to the relatively neglected potential of the Namibian offshore basins.
Following basin reconnaissance using sparse 2D seismic grids, 3D seismic data is being acquired over many of the most attractive blocks awarded in Namibia. This study describes the results of a fast-tracked integrated project delivering a dual-sensor 3D broadband seismic and seismic attribute analysis to provide increased understanding of petroleum systems and risk elements, prospective resource volumes and high-grading and de-risking drilling targets.

Introduction – Geological Setting

Namibia is a frontier region for exploration with evidence of a working petroleum system. The presence of the Kudu Gas field and oil seepage slicks combine to provide strong indications of hydrocarbon charge. Namibia's location within the South Atlantic Margin also adds to the geologic rationale for prospectivity. Brazil and Namibia are on opposite sides of the South Atlantic conjugate margin, sharing geological history and containing similar petroleum systems. Good quality source rocks have been penetrated all around the South Atlantic margins and other recent discoveries within the Atlantic are pushing the proven areas both north and south from the 'traditional' salt basins, opening up the region for further potential discoveries.

The studied area is a 3,500 km^2 3D seismic survey covering most of Block 2312A where water depth varies between 700 and 1800 m, and is part of a four block licence operated by Chariot Oil and Gas over blocks 2312 A&B, 2412 A&B (northern half) which straddle the Luderitz and Walvis basins (Figure 1). The deepwater regions of the Luderitz and Walvis Basins are virtually unexplored with only four wells drilled on the shelf to date, in an area similar in size to the prolific UK North Sea Central Graben, where hundreds of exploration wells have been drilled.

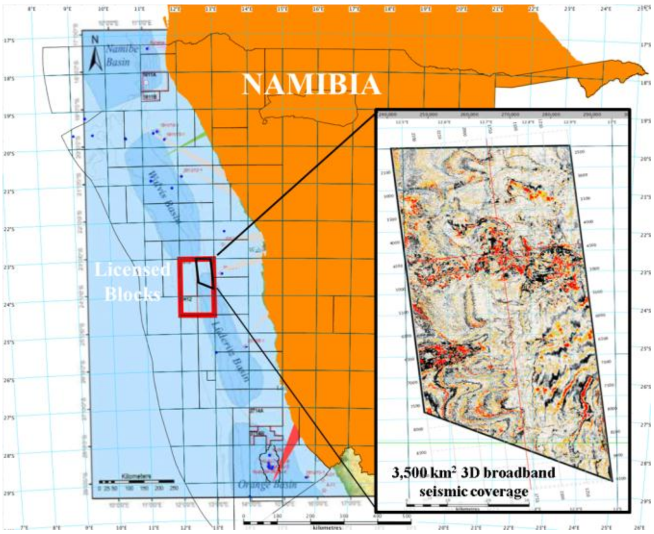

Figure 1 *Base map showing the location of the licensed blocks and the broadband 3D seismic survey.*

The study area lies adjacent to a shelf area with proven thick deltaic sands and current seismic mapping indicates that these sediments have been reworked via canyon systems into the slope and deep-water areas covered by this survey.

Project Objectives

The current project is an example of an integrated multidisciplinary project, started with the acquisition of 3D dual-sensor broadband seismic data through time processing to depth imaging supplemented by interpretation and attribute analysis, using advanced seismic reservoir characterisation workflows to assist prospect delineation. This project aimed to accelerate the exploration stage by delivering high quality seismic data in a short time using all the benefits of broadband seismic data in underexplored frontier deep water setting. This paper will concentrate mainly on the interpretation aspects of the project, showing the advantages of dual-sensor broadband seismic in this frontier area without well control.

Method and Theory

A 3,500 km^2 3D seismic survey was acquired between October 2011 and February 2012. The data was acquired using a dual-sensor towed streamer configuration - an acquisition method which uses co-located pressure and velocity sensors to allow the recording and separation of the upgoing and downgoing wavefields. This wavefield measurement allows the removal of the receiver ghost (Tenghamn et al. 2007). With the dual-sensor acquisition system, a broader range of frequencies can be recorded and the streamer can be towed deeper, significantly reducing the noise from the sea surface. The broader frequency input for inversion allows greater stability, resolution, and should improve the accuracy of rock properties estimated from seismic data.

With the acquisition finished early in 2012, the time and depth processing part of the project was completed by mid-November 2012. For depth imaging and velocity model building a hybrid tomography technology was used, which is based on beam technology and provides a unique and flexible tomography solution by picking 3D residuals in beam migrated space and exploring the multi-parameter nature of the wavelets in the tomographic update (Sherwood et al, 2011). As a result, within the same year the broadband PSTM and PSDM datasets were available for reservoir characterisation studies and attribute analysis, which were carried out during November – December 2012.

Qualitative Seismic Interpretation

Seismic interpretation was able to commence with the fast track time processing cube, obtained in May 2012 – just three months after acquisition was completed. While the depth and time processing was on-going, preliminary mapping was performed with identification of canyon-head channels and deep-water fan plays. Large submarine channel sand complexes appear to be deposited that have sharply erosional bases. Their sinuous, meandering geometry suggests relatively gentle slope gradients at the time of deposition. These channel complexes are evident in a thick section interpreted as the Upper Cretaceous sediments. The sands are distinguishable on the basis of seismic character in vertical section and horizontal map view from the background deep marine shales that exhibit regular polygonal faulting patterns associated with rapid de-watering of the shales. These encasing shales are likely to form a good top, base and side seal to any potential hydrocarbon accumulations in structural and/or stratigraphic trap configurations.

Upon receiving the final PSDM volumes in early November 2012 relative band-limited pre-stack inversion for Acoustic Impedance (Ip) and Shear Impedance (Is) was performed over the entire dataset. Figure 2 illustrates example cross-sections and map views through one of the identified deep-water channel features. Interpretation of such complicated reservoir architecture can be more easily performed in the Impedance domain as:

- Impedance represents layer properties rather than reflection boundaries
- Wavelet effects in the data are removed or minimized
- It provides better indication of the lithology and variation of layers in a relative sense
- Noise level is reduced by the inversion process

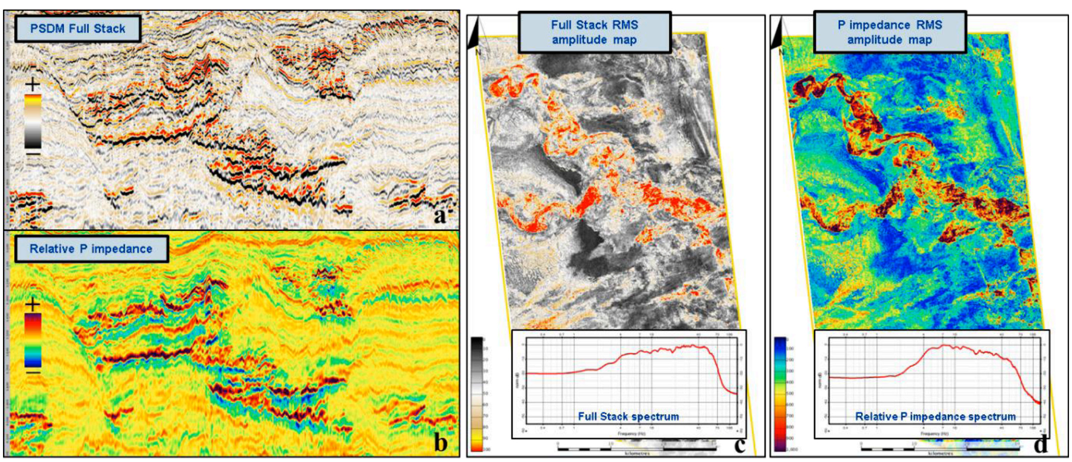

Figure 2 *Deep-water channel complex (Upper Cretaceous in age) a) Cross-section of PSDM Full Stack, b) Cross-section of Relative P-impedance, c) Full Stack RMS amplitude map and spectrum, d) P-impedance RMS amplitude map and spectrum.*

The broadband seismic acquisition has preserved an abundance of low frequencies in the data, making it possible to estimate absolute elastic properties, using the derived velocity field and an empirical density function for sand-shale lithologies at these depths. In Figure 3a the cross-section of absolute P-impedance is presented and in Figure 3b relative P-impedance and velocity spectra are shown. The seismic data itself contains recorded frequencies down to 3-4 Hz, while seismic velocities can potentially be used to fill the low frequency ‘gap’ in the data below seismic bandwidth. In this scenario, without a traditional low frequency model combined with well information, absolute rock properties can be estimated. Although this is an approximation, due to the high data quality and detailed velocity model obtained, the estimated absolute properties are close to the real values, (as has been demonstrated in other studies, for example, Reiser (2012)) and this method can be applied in frontier areas with limited or no well control.

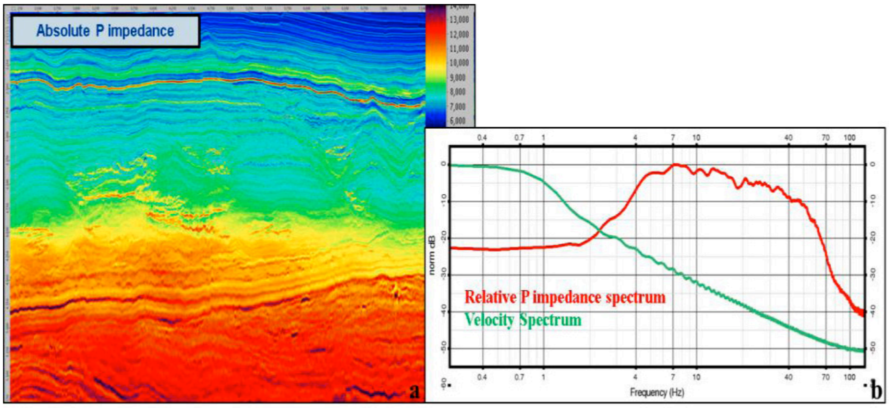

***Figure 3** Absolute rock property estimation using broadband seismic and seismic velocities without well control. a) Cross-section of Absolute P-Impedance, b) Spectrum of Relative P-impedance (red) and velocity spectrum (green).*

Spectral Decomposition is acknowledged as an effective seismic attribute to map channels and highlight geological features. These seismic data were decomposed into a series of seismic frequency bands between 5 and 90 Hz with 5 Hz increment. Figure 4 shows an example of a Spectral Decomposition display with a three-colour blend (CYM) of low (10 Hz), mid (30 Hz) and high (80 Hz) frequencies represented in different colours. The image demonstrates the benefits of broadband data, enabling high resolution imaging of fine geological features at a depth of around 2500 m below the seabed. Several key geological features can be highlighted on Figure 4: large channel complex (A), deep marine shales, represented by polygonal faulting pattern (B), erosional canyon entry points of submarine flows (C) and edge of the platform (D).

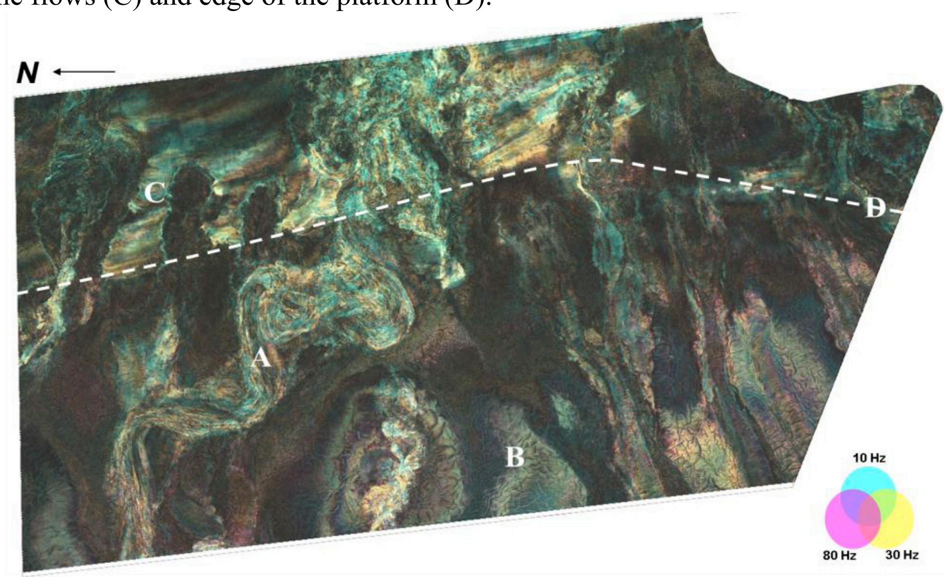

***Figure 4** Spectral Decomposition attributes*

The studied region shows seismic evidence of abundant sandstone reservoirs at multiple levels in a deep-water setting similar to the prolific deep-water channel systems which are well documented in the offshore of Angola to north of this study area. As an example, Figure 5 illustrates a deep-water sinuous channel complex from the Dalia field, offshore Angola, compared to one of the mapped Namibian channel complexes, which is twice as large and contains similar geometries and multiple channel configurations

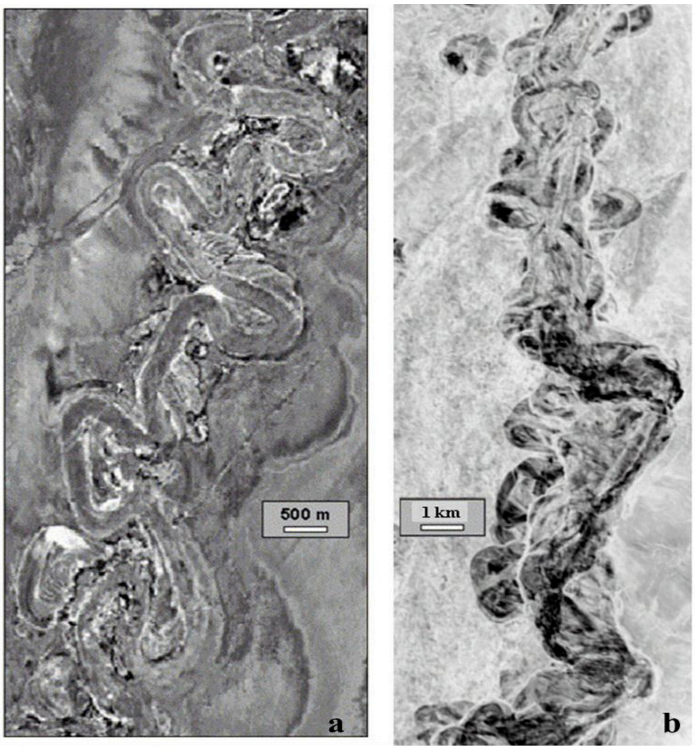

Figure 5 *Angolan sinuous channel analogues. a) Lower Miocene Green Channel Complex, Dalia field, offshore Angola (reproduced from Abreu et al., 2003), b) Channel Complex, offshore Namibia, interpreted to be of Upper Cretaceous age.*

Conclusions

The study demonstrates the advantages of using dual-sensor broadband acquisition techniques in a frontier exploration area. Within a collapsed timeframe both time and depth processing was performed followed by seismic reservoir characterization and attribute analysis. The tight integration of acquisition, processing and quantitative seismic interpretation has allowed the operator to evaluate the prospectivity and high grade leads for detailed analysis in a shortened period of time. The use of dual-sensor streamer seismic data has enabled reliable elastic properties to be derived in a frontier area without well control. The clear imaging of channel sand geometries has significantly de-risked a critical element of the play in this petroleum system.

Acknowledgments

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