Extending the Limits of Technology to Explore Below the DHI Floor; Successful Application of Spectral Decomposition to Delineate DHI's Previously Unseen on Seismic Data

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Summary

The field of interest is one of ExxonMobil's development assets in offshore West Africa discovered in the late 90's. A main development well was drilled subsequently in an attempt to confirm additional reserves in an adjacent fault block. The fault block was located above what was thought of as a field-wide oil-water contact, but the well surprisingly encountered wet sands. Application of Spectral Decomposition helped us explain this dry well as well as delineate a new group of anomalies never seen before on the seismic data. These anomalies were deeper than any penetrated interval in the field and below what was thought of as the DHI floor or the limit of our DHI detection. The anomalies were on the opposite side of the fault from the dry well but on the same side of the fault as the original discovered reservoirs, thus could be reached easily from the platform. The anomalies showed class 2 DHI responses at low frequency which was consistent with the structure. A new development well was finally drilled two years ago to test this interval and discovered 160 meters of net oil sands thus adding significant amount of reserves to the field and confirming our prediction.

The field is comprised of deepwater channel complexes draped over a complexly faulted high-side closure.. The discovery well was drilled in late 90's by the "Well A" exploration well and penetrated three oil bearing channel sand complexes comprising of Class III to a Class II type DHI responses, from shallowest to deepest, respectively. Near-field development drilling concentrated on adjacent fault blocks and similar depth anomalies due to earlier drilling results and previous rock property predictions for the area limiting the DHI play, i.e. the "DHI Floor", to depths around those of first exploration wells. However, in our attempt to explain the results of the dry well and look for more potential in the area, one of the technologies we experimented with was Spectral Decomposition. The application of Spectral Decomposition in this area was partially responsible for understanding the difference between the wet from hydrocarbon response on the seismic data. It also allowed us to extend the concept of "DHI floor" to a new limit as new and additional anomalies not previously imaged on the seismic data were delineated. Spectrally Decomposed Far-Offsets and Spectrally constrained AVO datasets revealed the expected response for Class II type direct hydro-carbon indicators, showed clear reservoir amplitude conformance to structure, improved the stratigraphic details for higher confidence interpretation and ultimately supported the presence of thick high-quality reservoir section beneath the existing discovered reservoirs help potentially helping to extend the life of the field. Based on these results a new development well was designed and drilled two years ago to a target picked on the basis of the spectral decomposition analysis. The well penetrated over 160 meters TVD depth of net oil sands, confirming the presence of thick, high-quality oil sands deeper than any encountered oil pays in the field. In this paper we will summarize our pre-drill analysis and our post-drill results.

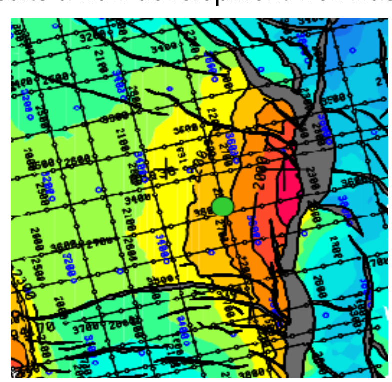

FIGURE 1: STRUCTURE MAP FOR RESERVOIR 2 SHOWING DISCOVERY WELL A

Introduction

The field presented in this paper is part of an ExxonMobil operated development area in offshore West Africa. The field was originally

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discovered by the exploration well, "Well A", which penetrated four reservoir intervals. The reservoirs are interpreted to be southeast-northwest and east-west trending confined deepwater channel complexes which are Miocene and Oligocene in age. The channel systems are situated on a high-side fault-dependent closure juxtaposed against a large counter regional fault (Figure 1). The "Well A" discovery well encountered about 120 m of net pay in 3 oil bearing reservoir intervals and a thick wet sand in the deepest objective. "Well B" was a subsequent development well designed to help prove additional reserves in an adjacent updip fault block. The targeted anomaly was above what was interpreted as a field-wide oil water contact (Figure 2). The interpreted anomaly was recognized as high impedance on the near with possible phase reversal to low impedance on the fars that could not be validated due to complex stratigraphy. Surprisingly, the well encountered thick wet sands which invalidated the field-wide oil water contact scenario and reduced our expected volumes for the field. An attempt was made to explain the results of "Well B" in light of the seismic response. Investigation of the seismic data utilizing Spectral Decomposition was chosen as one of the technologies to test.

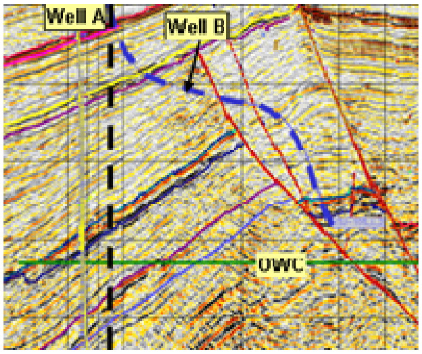

Figure 2 Hi-Res Near Stack showing Original Exploration Well "A" and the Development Well "B"

Rock Physics and Modeling

Rock properties for the hydrocarbon and wet reservoirs were extracted from the wells in the field. Ranges of reservoir properties were modeled to examine the expected signature for increasing reservoir quality filled with oil. The modeling showed that the reservoir in the deeper portion of the field is generally a Class II AVO anomaly internally, with localized areas of class I. The overall offset character for the oil reservoir consists of weak to moderate near-offset amplitude which could become brighter on far-offset data with increasing reservoir quality. Likewise, decreasing reservoir quality shows a class IIP to class I response with much weaker amplitudes observed on the far-offsets; this was our most likely scenario. The wet sand response is separable from that of hydrocarbon as it is primarily a high impedance response decreasing in amplitude with offset (Figure 3). This was the response for the wet sand encountered in the development well "Well B". Subsequent detailed pre-stack and pos-stack analysis of the seismic data revealed the anomalies to be primarily high impedance with no AVO especially from the original, long- offset 3D survey that shot in the area and the seismic response seemed to agree with the modeling results. The "Well B" was planned and drilled utilizing a recently shot, short-offset, high resolution (Hi-Res) 3-D survey (Figure 2). The response observed on the Hi-Res far off-set data indicated that hydrocarbons could be expected in the target interval at the planned "Well B" location. However, "Well B" encountered wet sands in the objective section. With the disappointing results from "Well B", the Hi-Res 3-D survey we re-analyzed and it was discovered that the response observed on the Hi-Res fars was a result of mis-stacking due to severe non-hyperbolic events.

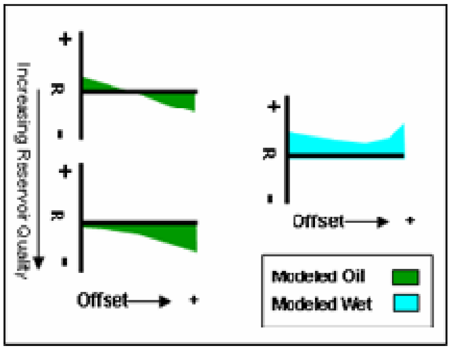

Figure 3: Rock Property Models for the Deeper Objectives from the Exploration well "Well A"

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Spectral Decomposition

Spectral Decomposition Technology (SDT) is a tool that allows for the extraction of frequency and amplitude information from seismic data with resolution previously thought unattainable. In particular the characteristics of the algorithm (Castagna et al., 2002) imply that this type of SDT performs an adaptive (namely, not fixed but multiple window) spectral analysis of the seismic traces. SDT was used to delineate deep section spectra and therefore optimize the deeper section bandwidth. SDT was performed on several far-offset traverses over the prospect. Analysis of the resultant frequency gathers revealed that the majority of the signal's strength for the prospective reservoir interval was confined to a narrow band of frequencies: primary to 15 Hz and below or centered on 11 Hz. Utilizing this information, a bandpass filter was originally designed and applied to the seismic data to preserve the observed most significant bandwidth of the reservoir and attenuate all energy above 15 Hz. The resultant dataset showed lower apparent resolution, the expected response for the discovered reservoirs, and no anomalous response at the well "Well B" location. However, several pronounced low impedance anomalies versus background appeared in the deeper section. These anomalies were below any existing discovered reservoirs which provided a step change in the interpretability of deep DHIs and the stratigraphy from the seismic data. The new events were not visible on the original far-offset data (Figure 4) and showed the modeled response for a Class II DHI, of low impedance on the far offsets which was consistent with structure. A new development well was designed and subsequently drilled on the basis of the findings in this study. Based upon the results of the "Well C", a new drilling program is being planned to develop hydrocarbons in this deeper interval.

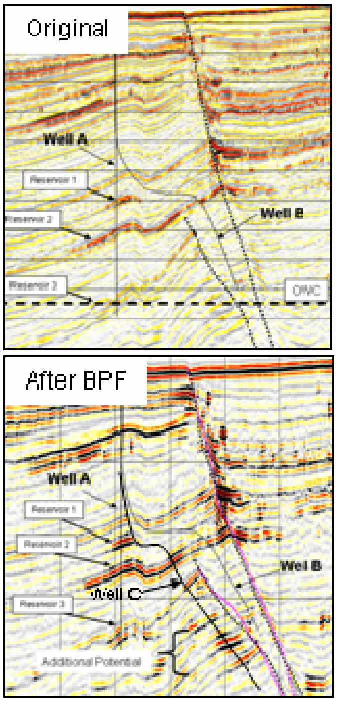

Figure 4: Comparison of Original Far-Stack with that after Optimizing bandwidth from Spectral Decomposition

Enhanced AVO Attributes

The ExxonMobil DHI-AVO Best Practices recommends that many factors of the seismic data must be evaluated in order to achieve an understanding of the drilling risks. Some of the recommendations involve analysis of both Near- and Far-Stack volumes, and the generation of an AVO attribute (essentially, the scaled envelope difference between the Far- and the Near-Stack response). To generate such volume, the near and far offsets bandwidth must be balanced, and hence would have similar wavelet properties. The selection of the bandwidth balancing parameters is one of the crucial but also potentially most subjective issues. SDT offers the best approach of selecting the "right" bandwidth balancing parameters by generating frequency gathers to determine the bandwidth on both nears and fars with depth. Subsequently, we can keep those frequency panels that comprise the bandwidth of interest on both datasets, and then sum those panels from the near stack decomposition to create a pseudo-filtered near-stack and do the same for the fars. Utilizing this methodology on our 3D volumes, scaled Spectral AVO Envelope cube was generated from the new pseudo filtered near and far cubes. The new cube showed the expected AVO

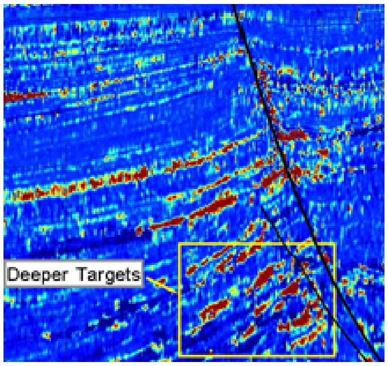

Figure 5: Spectral AVO Section Showing Shallow and Deeper Targets. Positive AVO is in Red

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response for hydrocarbon bearing sands (Figure 5), which was also consistent with structure. The new filtered fars and the Spectral AVO cubes were used to design and position our development “Well C”.

Results

The proposed development “Well C” was drilled three years after the development “Well B”. The well around 160 meters (TVD) of net oil sands in the objective reservoir targets, which was better than anticipated. The well results added significant volumes to the development of the field, and validated the pre-drill DHI and stratigraphic prognosis using the Spectral Decomposition technique.

Conclusions

The application of Spectral Decomposition technology was an effective way of delineating deeper targets not seen before on original seismic data for DHI and stratigraphic interpretation. The delineated DHI response matched what was expected for better reservoir quality Class II hydrocarbon bearing sands. Also, the new optimized seismic data allowed interpretation of stratigraphic patterns not seen on the original data and gain confidence in resource estimates. Enhanced AVO attributes (Spectral AVO) offer the possibility of rapid volume scanning for highlighting valid AVO anomalies and deeper targets originally thought to be below the DHI floor.

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EDITED REFERENCES

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