Time-Lapse Prestack Seismic Inversion to Delineate Undrained Reservoirs – Simian Field, Offshore Nile Delta, Egypt *

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Abstract

The Nile Delta Basin is a productive gas province, which has been under exploration and development for decades. Even though the basin has been studied widely using geologic and geophysical methods, mapping un-drained sweet spots from seismic data still one of the major challenges. The main driver to acquire time-lapse seismic over the Pliocene gas fields was to identify additional development opportunities by imaging hydrocarbon drainage patterns or pressure depletion. As feasibility studies promise 4D signals over these reservoirs and dynamic versus static volume discrepancies indicated that the remaining opportunities are good enough. As the upcoming drilling campaign is targeting the remaining volumes of one of the Pliocene reservoirs in the offshore Nile Delta “Simian field”, this study compares different vintages of seismic data shot over the WDDM concession in the search for 4D effects attributable to changes in reservoir conditions due to production. The seismic data used were the 2006 survey as a base survey and the 2014 survey as a monitor survey. As these datasets were not acquired or processed as a 4D survey, reprocessing of the seismic datasets was required in order to distribute the data onto a common grid. The common grid used was that of the 2014 survey. The two surveys were matched in terms of amplitude, phase and timing through the use of filters. This was done in a global, local and residual sense, with each matching stage becoming more intolerant of differences. The design of matching filters was conducted away from producing fields (Scarab-Saffron). As part of the reprocessing, the 2006 survey data bandwidth was enhanced and noise reduced. Partial angle-stacks from the base and the monitor surveys were separately inverted to the acoustic impedance (Zp), shear impedance (Zs), and density. The analysis of the individual inversion results and the 4D differences indicated that the liquid gas throughout the field was widely exploited. The production history of the wells was found to be consistent with the lower Vp/Vs ratio and the higher Zs values indicating depletion. This is in agreement with the modeled response predicted by the feasibility study, due to changes in reservoir pressure and saturation. Both Zp and Vp/Vs are affected by pressure changes as well as saturation changes, while the Zs was found to be the most reliable pressure-changes indicator.

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• Problem:
  The challenge of infill drilling is to find relatively un-drained areas with low risk of water encroachment.

• Solution:
  Qualitative 4D seismic Analysis may therefore be able to highlight areas of less depletion and higher infill potential.
Study Area Location

- The Simian field is found offshore Egypt as part of the proven gas reserves in the West Delta Deep Marine concession (WDDM) of the Nile Delta.

Modified from Samuel et al. (2003).
The Simian field is believed to be a slope channel complex deposited on the Nile delta slope in the early Pliocene within El-Wastani formation.

Modified after Abdel Aal et al., 2006.
The reservoirs consist of complex submarine channel systems. The porosity ranges from 24 to 36%. 
4D Feasibility

What happens with production?

- Pore pressure decreases and Effective pressure increases.
- Water saturation increases and HCWC moves up.
- Reservoir compacts (Thickness decreases).

These effects change the elastic rock properties, hence the seismic amplitudes.
3D Feasibility

From reservoir engineers by 2014

Pore Pressure becomes 100 bars → 58% drop
Water Saturation becomes 0.8 in flooded areas → 250% increase
Cumulative Production And Current Rate

- Cum Gas, bcf
- Current Gas Rate, MMscf/d

<table>
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<th>Cum Gas, bcf</th>
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Workflow

Base (2006) Full Stack

Monitor (2014) Full Stack

Time Shift


Monitor (2014) Angle Stacks

Time strain

= +

Monitor (2014) Angle Stacks

Shifted Seismic

= =

Monitor (2014) Angle Stacks

Prestack Inversion (Monitor) (Zp, Zs, Dn & VpVs)

4D Interpretation

Prestack Inversion (Base) (Zp, Zs, Dn & VpVs)
P-Impedance

Difference

2006

2014

Difference

GEO 2018
P-Impedance

2006

2014

Difference

2006

2014

Difference
S-Impedance

2006

2014

Difference

2006

2014

Difference
Vp/Vs

2006

2014

Difference

GEO 2018
4D Interpretation

Undrained Area

Fault

Possible Leakage

Moderate Production Area

Low Production Area

High Production Area

Amplitude

Time Strain

P-Impedance
Conclusion

- The effect of pore pressure is higher than the effect of the water saturation on the 4D seismic amplitude signature.

- The Time Strain (derived from the Time Shift) can be used to detect the compaction and depleted areas resulted from the production.

- The integration between Time Strain and Prestack inversion volume differences is useful to delineate:
  - High production areas.
  - Low production areas.
  - Undrained areas.

- Based on this study, an infill well had been proposed on the undrained area.
Acknowledgement

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Thank You..