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Mapping Reservoir Changes Using 4D Seismic Data at Simian Field, Offshore Nile Delta – Egypt

A Thesis Submitted for the Degree of Doctor of Philosophy
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(Geophysics)

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Abstract

Time-lapse seismic inversion method to reservoir management has proven to be a vital tool in the oil industry because of its effectiveness in tracking the pressure and saturation changes within the reservoir as well as identifying isolated bypassed accumulations.

The 4D inversion process is critiqued to explore the pros and cons of 4D seismic inversions and how these could be improved. The major draw backs of the method are dependence on well log data quality, wavelet estimation and initial model construction whilst the potential gains are improved geological and geophysical classification of a seismic volume to a higher level than is possible with full-stack seismic data alone

A 4D pre-stack simultaneous inversion was applied at the Simian gas field, part of the West Delta Deep Marine concession(WDDM), offshore Egypt with the aim of exploring the potential of this approach for time lapse quantitative interpretation. The Simian field is submarine channel based gas reservoirs that extend laterally over 25 km^2. The nature of this channel has been well defined using full-stack seismic interpretation and from this producing wells have been drilled.

Four wells are analyzed in a 4D rock feasibility study to demonstrate that 4D seismic inversion will be beneficial and show which physical attributes will help to estimate saturation and pressure changes in the filed using time lapse seismic data. The extracted attributes were the shear and acoustic impedances was shown to give the optimum separation for the effectiveness of the saturation and pressure changes.

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A base angle stacks 15°,15-30°,30-45° and monitor angle stacks 0-15°,15-30°,30-45° from simian field were inverted for P-wave impedance (Zp), S-wave impedance (Zs) and density using 4D seismic inversion method, and from these attribute cubes shear impedance and acoustic impedance was mapped across the seismic volumes, shear and acoustic impedance difference volumes were used to map the pressure and saturation changes through the reservoir as well, direct comparison is made between the difference output volumes for the original seismic amplitude to emphasize the benefits of 4D seismic inversion and justify the process.

A base and monitor seismic surveys from the Simian field were inverted during this research. The field has passed through high gas production at the first. These seismic surveys were analyzed for time-lapse impedance changes due to the differences in the produced hydrocarbons and water production. Check-shot corrected well data as, well as interpreted horizons, were integrated in the inversion process. Two independent wavelets were extracted from both base and monitor surveys, and combined to form an all-encompassing frequency and amplitude wavelet. The base and monitors were jointly inverted. This is because of the reduction in inconsistencies that are associated with independent inversions of surveys and the production related changes expected in time-lapse inverted seismic data.

Inversion results showed, the impedance difference across the field for the various monitor surveys. Areas surrounding production wells show great changes in impedance. A statistical analysis of the inversion results also shows increase in impedance across the field for the subsequent monitor. Structural and stratigraphic interpretation of the time-lapse inverted data also confirmed that the area of high production. This high production supported the impedance changes within the field.

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Time-lapse acoustic impedance inversion of the Simian pre-stack seismic data has revealed the impacts of production, dynamic fluid changes on main identified geologic structures, fluid front migration, fluid communication across structures and segments and other identified stratigraphic elements.

The results achieved in this study suggest that the application of the proposed 4D seismic inversion methodology leads to quite reasonable predictions. Hence, using this method instead of the other 4D inversion methods will have the effect of increased production and economic efficiency.

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