4D Monitoring: Example of 4D Interpretation in Lower flanks systems, Dália - Angola

Joyce Vemba, Sonangol EP/DEX, Luanda, Angola; Francisco Cunha, Sonangol EP/DEX, Luanda, Angola; Emmanuelle Brechet, TOTAL, Pau, France; Sonja Maultsch, TOTAL, Pau, France; Sylvain Toinet, TOTAL E&P Angola

Summary

Some field of Lower Congo Basin deep offshore are composed of heterogeneous turbidites channels of Miocene age located in Angola at water depth that range between 700 – 1500 meters. The Dalia field, located in Block 17, is characterized by four main sedimentary complexes, called Upper Main Channel, Lower Main Channel, Lower Flanks and Camelia. This area is characterized by high resolution seismic data (10 m) that is used for fine reservoir characterization and monitoring. After one year and half of production, a first 4D seismic survey was acquired. This 4D seismic monitor bring more accurately interpretation on facies distribution and a better understanding of reservoir communications. The 4D effects seen on Dalia are large since time shifts associated to production were used to interpret 4D signals and upscale them inside the reservoir model.

Introduction

The Dalia field is located in Southwest of the Tertiary Lower Congo Basin (Figure 1). It is divided into four main sedimentary complexes that belong to turbidities deposits of Lower to Middle Miocene. Structurally, it does belong to a transitional Zone limited by two turtle back anticline and its surrounding affected by Albian salt layer.

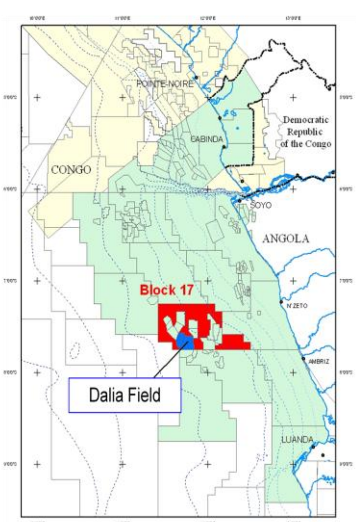

Figure 1. *Location of study area*

The studied area, named Lower Flanks, is located in eastern part of the Dalia field. It is mainly composed of unconfined turbiditic deposits formed by different lobes separated by shaly deposits.

After one year and half of production, a first 4D seismic survey was shot on all Dalia field area in order to understand the reservoir communications inside these heterogeneous channels deposits. For 4D interpretation purposes, we used 4D amplitudes and 4D attribute dV/V issued from an internal warping process, which corrects time shifts between Monitor and Baseline surveys.

Methodology

The aim of the 4D interpretation on sheets/lobes of the Lower Flanks is to interpret the 4D anomalies present due production: depletion and water injection. 4D anomalies were compared to dynamic monitoring parameters such as MDT and PLT measurement in order to calibrate it.

4D effects are very large in amplitude and time shift due to unconsolidated sands because it has the significant variation of amplitude on depleted area.

The interpretation purposed is to generate amplitude difference from Base survey and Monitor survey and then to corrected the time shift. For this purposed, TOTAL performed in-house the warping tool that is an inversion approach the problem in terms of velocity changes and alignment to explain both time shift and amplitude changes (Williamson et al, 2007). It generated as result the time re-alignment of monitor seismic data (Figure2).

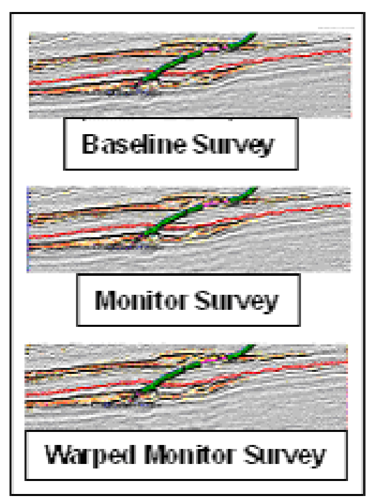

Figure 2. *Illustrate the time re-alignment monitor seismic data*

This warped monitor resulted also on the computation of the dV/V attribute (Figure 3) that is used for qualitative 4D interpretations with additionally 3D Band-pass P-impedance derived from pre-stack inversion and Architecture Element (AE) maps (Figure 4).

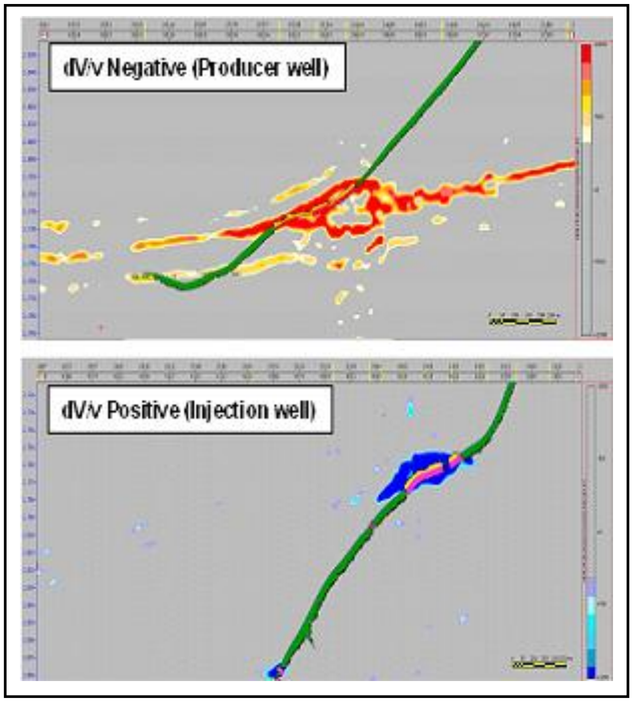

Figure 3: *dV/v attribute from warping result, extracting along the well path where negative dV/v corresponds to producer well a cause of depletion to bubble point and dV/v corresponds water injection*

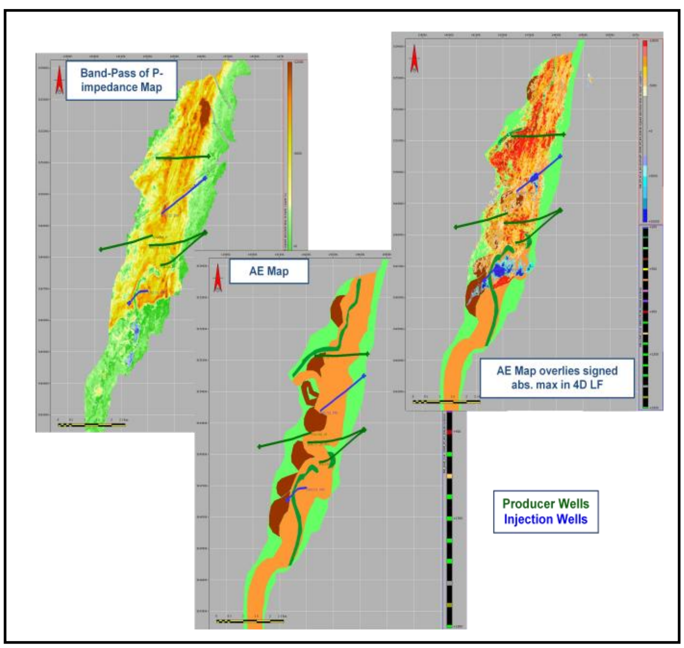

Figure 4: *From left to right – 3D band-pass of P-Impedance; Architectural (AE) Map and AE Map superimposed signed absolute max in Layer*

Once we have all necessary data for 4D interpretation, we compare 4D anomalies to facies extension limits to see if the geological model is predictive or not.

4D anomalies are then picked in 2D and 3D and are compared to dynamic monitoring parameters such as MDT, PLT measurements in order to calibrate it and Eclipse simulation results. 4D seismic data was useful to understand areas of water injection, depletion, rise of the WOC, fault sealing character and reservoirs communications

Results: 4D Interpretation and technology application

Once we have the mandatory 4D attributes cubes (4D amplitude and dV/V), we are able to start the seismic interpretation.

According to the Lower Flanks systems, the 4D interpretation is performed in unconfined turbidite deposits as lobes types. During the first step of 4D interpretation, 2D seismic boundaries are picked on isoproportionnal layers and compared visually to water saturation and fluid pressure obtained from reservoir simulation.

During 4D interpretation on lobes of Lower Flanks, we were able to detect the following 4D effects:

- ❖ Depletion in Oil around producers with negative dV/V signal
- ❖ Water in Oil around injectors and on WOC rise ups with positive dv/V signal
- ❖ Water in water around injectors with negative dv/V signal due to salinity effects

In the first case of 4D anomalies linked to depletion, we observe 4D anomalies linked to producers associated to strong depletions (-30 bars) and 4D anomalies linked to inter systems communication between the lobes deposit of Lower flanks and the confined turbidites deposits of Lower main channel. There is a significant lateral communication between two different turbiditic systems seen with negative dV/V signal (Figure 5).

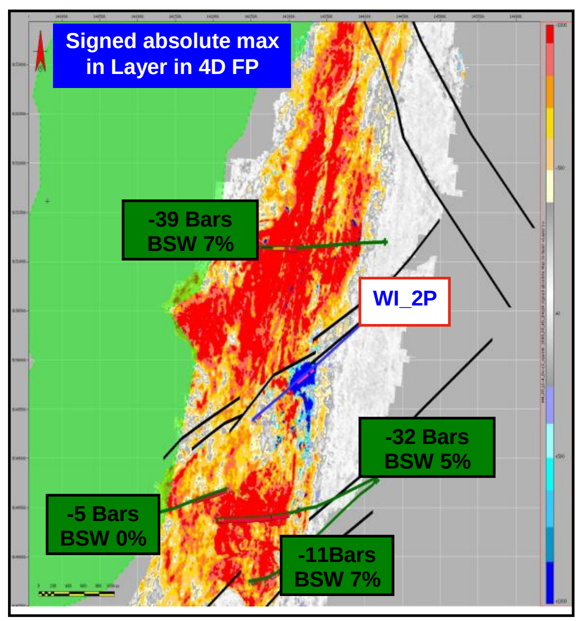

Figure 5: *Very good example of 4D effect: Depletion zone around producer wells (in green)*

On lobes systems, the oil pressure is very close to bubble point, where gas is rapidly associated to depletion and implies a negative dV/V.With 4D interpretation its possible to identify these depleted areas and allow to find undrained one for future infill wells.

The 4D allow us to interpret water injections anomalies and WOC rise ups. Large WOC rise ups were seen on the most produced lobes and were not predicted on reservoir model before 4D results. These 4D anomalies are positive deltaV/V when oil replace water and are located updip aquifers on reservoirs (Figure 6(a)). Here, the 4D effect is a mixed effect showing the WOC rise up (positive deltaV/V) and the water injection inside the water pool (negative delta V/V). The change of polarity occurs on the DHI seen on impedances section by amplitude extinction (Figure 6(b)). WOC rise up seen on some lobes reach 10 meters and were not predicted by reservoirs models.

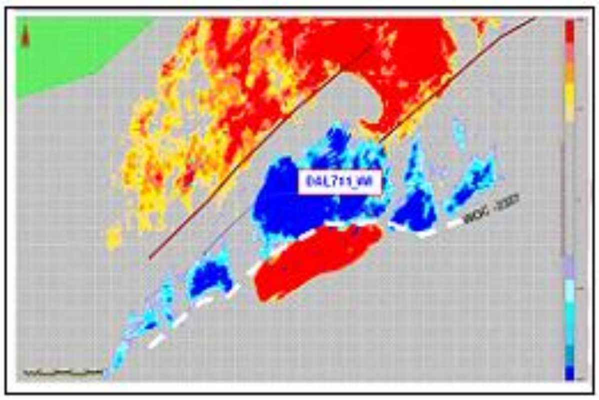

Figure 6(a): *dV/v attribute extracted on one lobe that observed the WOC rise up and water injection efficiency of the injector in oil pool (positive dV/V) and in water pool (Negative dV/V)*

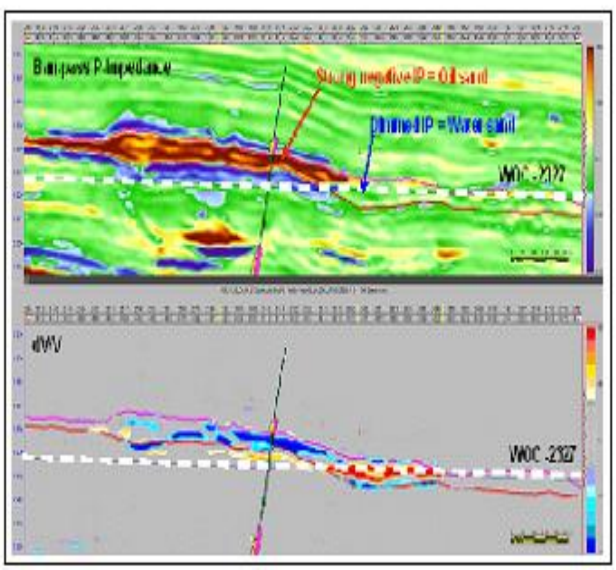

Figure 6(b): *Cross-section showing WOC rise up*

After 4D anomalies identification, we used the seismic attribute dV/V and propagate 3D Geobodies on this attribute constrained by seismic interpretation. For this purpose, we choose cut offs on dV/V attribute in order to have reliable 4D anomalies. These cut offs can be low since the 4D quality is very good.
After 3D geobodies propagation, we make sure that the 4D anomalies are consistent with geology by compating 4D anomalies to 3D impedances and AE maps upscaled inside reservoir models. Then, we upscale 3D geobodies extensions of water injection, depleted areas, etc… in fine geological grid of 40 X 40 m (Figure 7), where facies and petrophysical parameters can be updated according to 4D anomalies extension.

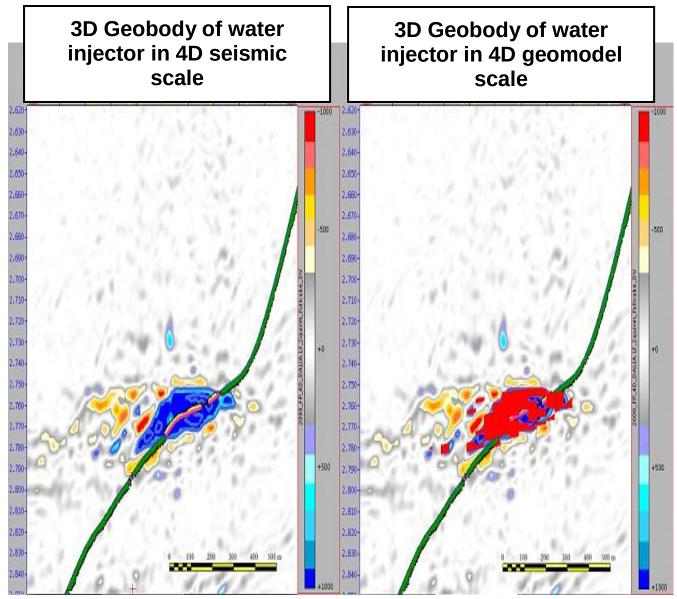

Figure 7: *(Left) 3D Geobody propagate on 4D seismic scale and (Right) upscaling of this Geobody in a fine geological grid model*

Within this volumetric 4D interpretation, we are able to make reservoir models more predictive for the future since we confront geological and dynamic knowledge at the same scale in 3D. At same time 4D helps us on the fault sealing behavior comprehension since some 4D effect is seen along faults and help us in changing some fault transmissibilities inside the reservoir model. It is useful to understand the vertical and lateral communication between the sheets/lobes and other complexes.

Conclusions

The 4D interpretation shown here was performed on all other systems and reservoir model prediction by changing some facies distribution, reservoir permeabilities and fault transmissivittties. Future work will deals with injected volumes computations on dV/V but also dIP/IP attributes in order to compare quantitative volumes with reservoir simulation volumes and PLT volumes. Can 4D be more quantitative?

Acknowledgments
I would like to thanks TOTAL E&P and its partners **StatoilHydro, Exxon-Mobil and BP** for be involving on this kind of integrated job and for permission to publish this paper.

References

Brechet E (Total E&P Angola)., Pillet W. (Total), Feroci M. (Fugro-Jason); 2008; “Seismic facies characterization and distribution in reservoir grid: Experience feedback”; Expanded Abstracts

Williamson, P.R., Cherrett, A.J., Sexton, P.A., 2007, “A New Approach to Warping for Quantitative Time–Lapse Characterisation”, EAGE, Expanded Abstracts

A.Gonzalez-carballo, P.-Y. Guyonnet and B. Levallois (Total E&P Angola); and A. Veillerette and R. Deboiasne (Total); 2006; “Repeated 4D Monitoring of the Girassol field (Angoal): Impact on Reservoir Understanding and Economics”, Offshore Technology Conference, Expanded Abstracts

Bush I., Rowbitham P., Janex G., Mazzotti A., Stuchi E. and Ciuffi S.; 2000; “AVO inversion of 4D Seismic for reservoir monitoring: An example on the Oseberg Field”, Petrophysics meets Geophysics, Expanded Abstracts