Crosswell Seismic Reservoir Characterization in Dom Joao Field, Brazil

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Abstract

Each borehole seismic technique has its advantages in imaging the subsurface, but the high resolution obtained using crosswell seismic imaging allows for a detailed survey of the reservoir. These results are enhanced when acquiring multiple profiles permitting a view of the entire field in two and three dimensions.

Petrobras supported a research project, with the technical participation of CPGG/UFBA to evaluate for the first time in Brazil, the different aspects of crosswell seismic through surveys carried by Schlumberger in Dom João (5 profiles) and Miranga (1 profile) fields, in October 2011. The target of this project was to investigate the response of Sergi and Catu formations to crosswell method, and secondarily provide, on Miranga field, a baseline velocity image to monitor a future CO_2 sequestration project.

This study focuses on the processing steps that allowed for the production of crosswell seismic images for the five profiles acquired in the Dom Joao field and its preliminary interpretation.

Introduction

Dom Joao Field, the second oldest commercial accumulation in Brazil, is located in Recôncavo Basin in northeast Brazil and has been under production since 1947. It extends by 23.5 km and is 0.6 to 3.5 km wide, with an area of 47.3 km2 (Fig.1). Structurally, is a gently dipping (1-5 °) horst, limited by a major fault zone with 400 to 500 m of displacement in the West, and smaller ones on its East side. Two thirds of the field is shallow offshore in Todos os Santos Bay, with average water depth of 3m. It produces from fluvial and eólic sandstones of Sergi formation, at depths from 146 to 376m. Nowadays the field is submitted to water injection and the comprehension or connectivity between injectors and producers through improvements of seismic reservoir characterization is of vital importance to optimize the EOR process.

Five crosswell seismic profiles were acquired for the Dom Joao field in Brazil focusing on the characterization of the Sergi formation. This project utilized Schlumberger's piezoelectric source, transferring energy through the formation and into a 20-level hydrophone array with a source and receiver level spacing of 3 meters. The average depth of investigation for all the profiles was between 100 to 550 meters.

Theory

A crosswell seismic project can be broken into four primary stages: a Pre-Survey & Planning stage, an Operations stage, Data Processing, and finally, Data Integration and interpretation (Figure 2).

During the planning stage, well and reservoir information, along with Petrobras' imaging requirements were collected and scrutinized to produce the most appropriate survey design for the project. In order to meet high resolution needs, the piezoelectric source matted with a 20-level hydrophone array was chosen as the acquisition hardware. The level spacing for both the receiver and source were to be 3 meters to allow for excellent vertical resolution combined with a source sweep of 100-1200Hz and 0.25ms sample rate.

This acquisition plan was then passed to crosswell seismic operations, where the field team would execute the planned parameters. Upon completion of acquisition, the data collected were found to be of good quality, as shown in Figure 3

The data processing for the project included standard crosswell processing to produce both the tomographic and seismic reflection images. This processing includes two main components: tomography and imaging (Figure 4).

During processing, direct-arrivals were picked for each of the profiles and were input, along with a Dom Joao field structural model, into a joint inversion algorithm to produce a tomographic velocity model (Figure 5).

The joint inversion works similarly to the standard inversion: the direct-arrival traveltimes, well deviations, and coarse geologic structural model, based on the client's well logs, are input into algorithm, which progressively updates the velocity model using a series of linear and non-linear iterations to minimize traveltime residuals. The difference is in the direct arrival inputs. The joint inversion allows for the calculation of a result using direct-arrival-time picks from multiple profiles, thereby creating a velocity model encompassing the entire region, rather than a single profile. Figure 6 illustrates a Petrel plot of the resulting joint inversion for the Dom Joao field.

Signal processing, including tubewave removal, direct-arrival removal, wavefield separation, and wavefield deconvolution, was applied to the data in parallel with the inversion stage.

The processed data were VSP-CDP depth mapped, as in Offset-VSP data processing and the velocity model from the traveltime inversion was used in tracing reflection ray paths to depth image the data.

The mapped data were then post-map migrated and an angle stack selection was made to the select reflection angle range that maintained adequate SNR. The final stacking angle range was selected for all the profiles and final staking image created. Figure 7 gives an illustration of the final composite image (tomographic image with wiggle trace overlay).

Interpretation

Three different approachs were used to evaluate the results: First we have tried to compare the velocity field from tomograms with velocity information derived from wells and surface seismic (NMO velocities). Unfortunatelly sonic logs weren't available for all wells but for those which we were able to build robust synthetic, we obtained a reasonable match with crosswell velocities. The different scales and 2D nature of crosswell made it harder to compare with velocities from high resolution surface seismic (3D - cell size equal to 5 x 5 meters).

Second, we evaluated the match between each of the composite sections. As can be observed on Figure 8, thye show a reasonable match, considering again the 2D nature of crosswell survey.

Finally we were able to compare the composites with the high resolution 3D surface seismic available on that area. In general, we achieved again a fair adjust between different data, probably once more associated with 2 and 3D natures of each different survey, but for our surprise their resolutions weren't so different (Figure 9). One of the potential explanations is related with the shallow targets which don't impose much absorption over surface seismic, and the higher signal to noise ratio made possible on surface survey.

Another interesting aspect was the observed difference on amplitudes, what somehow should be expected, considering the very different range of incidence angles used by crosswelll and surface seismic to image each point in subsurface.

Conclusions

In conclusion, high resolution images of the Dom Joao field reservoir were produced, giving a good example of the uses of the crosswell seismic technology within the reservoir zone.

After the crosswell seismic processing of the five profiles in the Dom Joao field, the final reflection images were compared with the well logs and surface seismic.

They show a good high, quality image of the subsurface in Dom Joao field and reflection images yield good ties with well logs, synthetic seismogram and surface seismic. Also, a velocity volume has been created using the joint inversion tomography, which is a great source for further study within the Dom Joao field. This velocity volume suggests that including more information into the joint inversion, by acquiring additional crosswell seismic profiles, can lead to a more accurate velocity model, better imaging of the subsurface and ultimately, an improved understanding of the Dom Joao field.

Aknowledgments

To Petrobras for the support to the project and permission to share its results.

References

Leite, E.P. de A . “An Integrated Evaluation of Dom João Field” – Internal Report Petrobras E&P-BA, Salvador, September 1989. (in Portuguese)

De Ross. L. F. “Reservoir Characterization of Sergi Formation in Northern Dom João Offshore Field” Internal Report – Petrobras R&D Center, Rio de Janeiro, October, 1988. (in Portuguese).

Rebeca, S. de A. Nascimento. “Caracterização Sedimentológica e Estratigráfica de Testemunhos da Formação Sergi, Campo de Dom João, Bacia do Recôncavo, Bahia, Brasil” – Monografia, Universidade Federal da Bahia, 2012

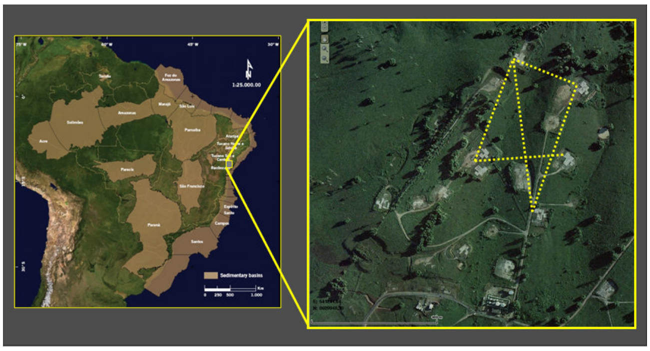

Figure 1 – Dom João Field location with position of crosswell profiles (yellow dotted lines)

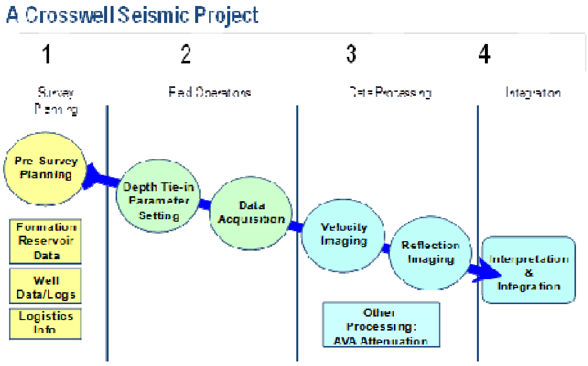

Figure 2. Crosswell Seismic Project Stages.

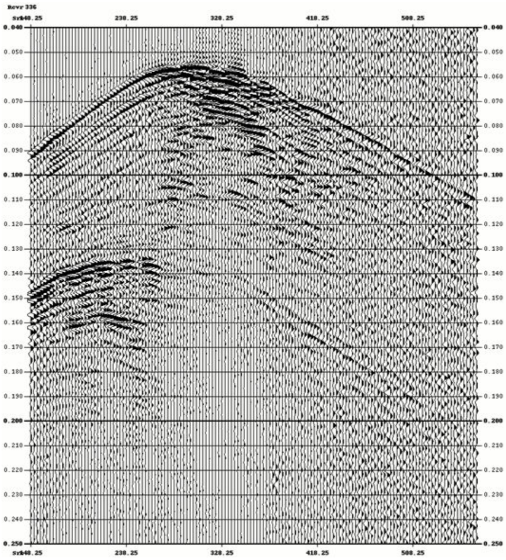

Figure 3. Sample Receiver Gather Dom Joao Field.

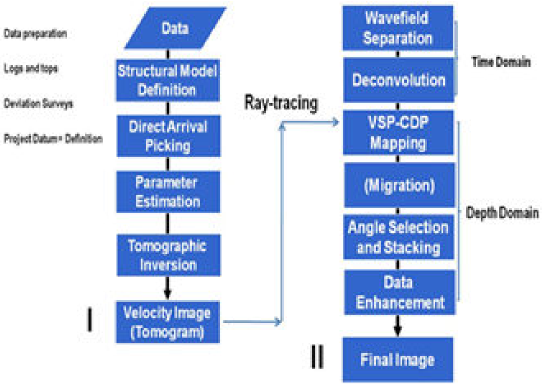

Figure 4. Crosswell Data Processing Workflow.

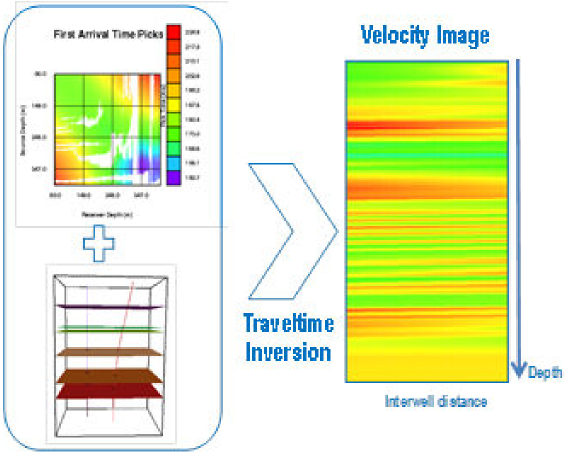

Figure 5. Crosswell Tomographic Inversion.

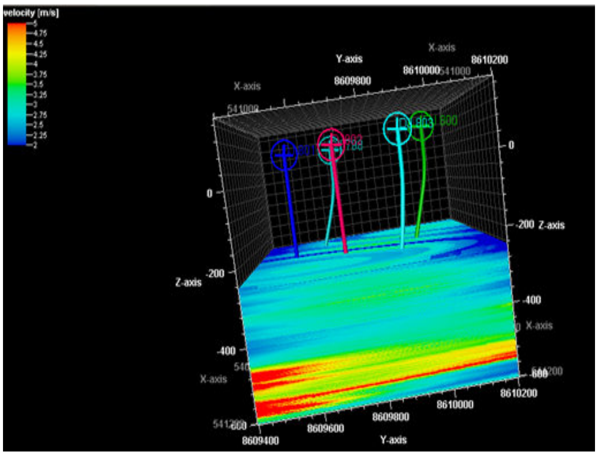

Figure 6. Dom Joao Joint Tomography 3-D Volume

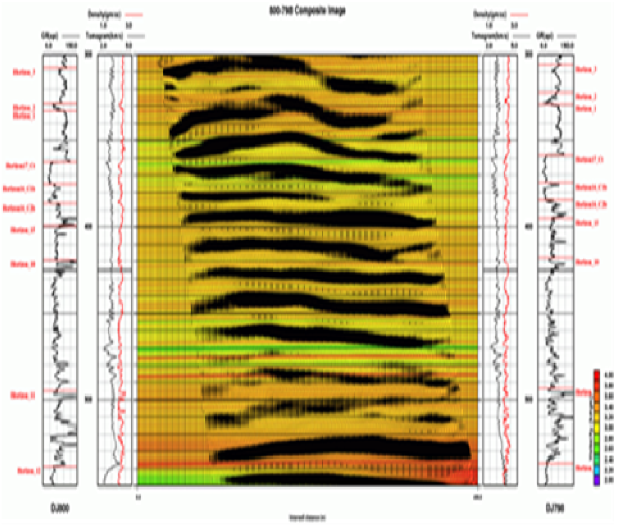

Figure 7. DJ800-DJ798 Composite Image

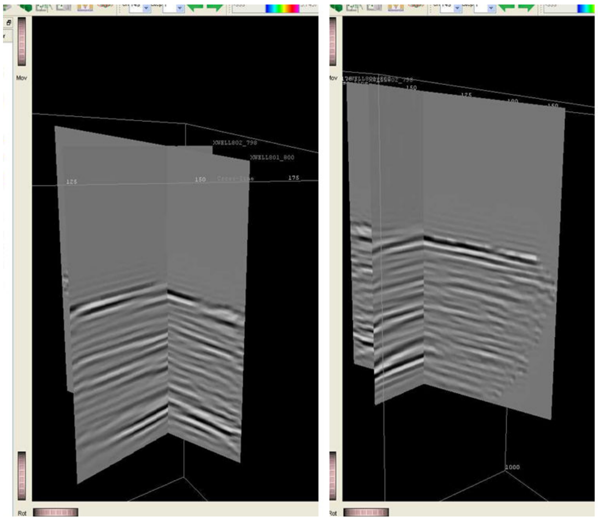

Figure 8. Comparison of composites: 802x798 and 801-800 (from two different perspectives).

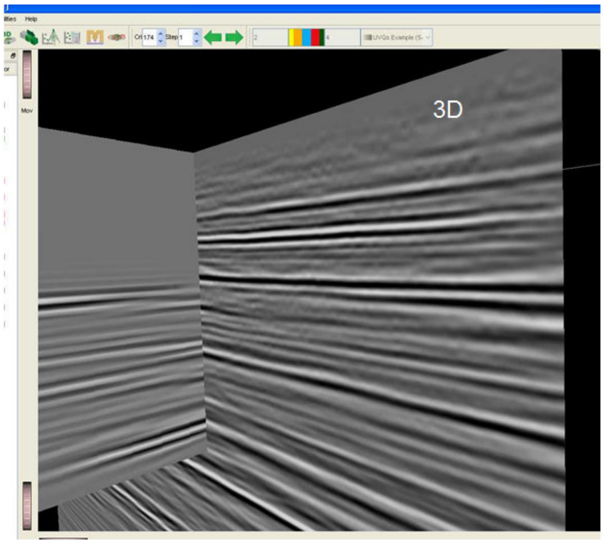

Figure 9. Comparison of composites: 802x798 and high resolution 3D