Analysis of seismic processing influence on Marlim field 4D

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ABSTRACT

We present and discuss some preliminary results of the seismic processing analysis, which have been developed in Marlim field time-lapse studies. This field has been used as a pilot project for time-lapse analysis. The second seismic survey was acquired to enhance the seismic resolution at reservoir horizons, instead of aiming at a specific time-lapse study. Preliminary feasibility analysis indicates low possibility of water flow monitoring, but we are still investigating and learning from the data. At the present time, only the presence of a secondary gas cap has been investigated. In this paper, we investigate the influence of seismic processing on monitoring maps.

INTRODUCTION

Marlim's field is located at Campos basin on continental Brazilian margin. It was discovered in 1985 and the first 3D seismic survey was acquired one year later. The second survey was acquired during March of 1997. At that time, the field had produced oil for six years and large amount of water had been injected. The two datasets are quite different. In the last survey, several acquisition parameters were changed to provide a high-resolution image.

The availability of the two datasets seemed to be a singular opportunity to start working with time-lapse technology. A 10-km square block was selected on the intersection of the surveys, in such way that the main water injection and the expected gas cap area were included, see figure1.

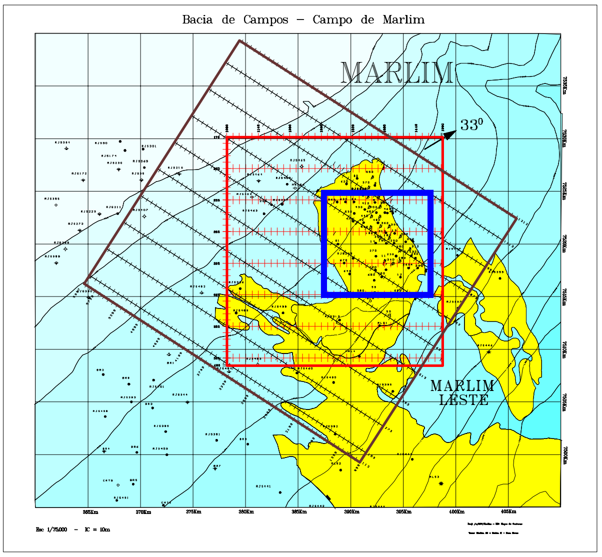

Figure 1: Location map of the pilot project.

Previous feasibility analysis have shown small probability of water flow monitoring, while 1D seismic modeling has pointed out better conditions for detection of the secondary gas cap. The pilot project was planned to be executed in two steps. In the first stage, the cross-equalization has been performed on the two available datasets. These datasets have been submitted to two quite different processing flows. Both the detection of secondary gas and the cross-equalization strategy definition have been established as targets for the first step.

The application of the previously defined cross-equalization technique on two similarly processed datasets has been defined as the second part of the pilot project. The difference between those two well-matched datasets has been supposed to be more suitable to monitoring changes in water saturation.

DATA ACQUISITION AND PROCESSING

Table-1 shows the main differences between the acquisition parameters of the two 3D surveys on Marlim field. The parameters of the second survey are suitable to produce a higher resolution image than the first one. It is a reasonable choice to match the second survey onto the first one, in such way that the cross-equalization has to filter information and not create it.

In the first step of the adopted strategy, the monitor stack data was resampled to four milliseconds into a cell of 25 X 75 meters by means of a 3D-spline interpolation. After that, both stack volumes were migrated using the migration velocity of the first survey. The cross-equalization sequence, described in the next section, matched the legacy data with the monitor data. These cross-equalized volumes are hereupon simply referred as Old and New data.

In the second stage of the 4D pilot project, the monitor data has been processed following the same sequence applied to the Old. Processing parameters like muting, multiplicity, maximum offset, DMO-bin sizes, decon window, etc. were defined as closest as possible. Stacking and migration were performed using the Old's velocity field. The reprocessed legacy data was then submitted to the cross-equalization procedure as defined above. This final cross-equalized volume is hereupon called New-rep data.

Acquisition parameter	Legacy data	Monitor data
Date	1986	1997
Inline direction	90 degrees	303 degrees
Receptor interval	50 meters	12.5 meters
Shot interval	25 meters	25 meters
Sample rate	4 milliseconds	1 millisecond
Number of streamers	1	6
Minimum offset	194	148
Maximum offset	3000	3600
Source depth	8 meters	6 meters
Streamer depth	10 meters	9 meters
Cell size	25 X 75 meters	6,25 X 25 meters

Table-1: Acquisition parameters.

CROSS-EQUALIZATION

The cross-equalization sequence applied to the monitor data consists of four steps: (a) global phase correction, (b) time shift correction, (c) sliding window matching, and (d) fine trace-to-trace matching.

The global phase correction consists in applying a constant phase rotation, which minimizes the differences between the legacy and the monitor stack volumes. The main phase discrepancies are caused by differences in source and receiver arrays, and between source and receiver depths as well.

Time shift corrections are computed using a trace-to-trace correlation algorithm. The corrections consist in static shifts applied to every seismic trace. Variation in source and receiver depths and tidal movements are supposed to be the main cause of the observed time shifts.

In the third step, a set of individual matching filters is computed. Each matching filter is designed to minimize amplitude, frequency and phase discrepancies that exist between two corresponding sub-volumes, selected on both monitor and legacy data. The selected sub-volume is defined by a box window, which may or may not include the reservoir horizon, depending on the box dimensions.

Finally, we compute and apply individual matching filters for each trace. Only samples above the reservoir are taken into account in the filter design.

DISCUSSION

Acquisition and processing strongly influence the final seismic image quality. Several questions remain to be answered: Is it always possible to get a reasonable matching of two datasets? Does the application of the same processing flow guarantee a good matching? What is the crucial step to be analyzed? Could we get similar seismic resolution by applying frequency filters or deconvolution? This kind of questions has encouraged us to start this work.

Seismic resolution depends on acquisition parameters, geology and seismic processing. Source and receiver array distribution and depths control the recorded frequency bandwidth. In seismic processing, deghosting, decon, spectral whitening and absorption compensation are traditionally considered when someone thinks about resolution. However, all imaging processes have to be taken into account. Stacking velocity, DMO bin size, and migration aperture have to be considered when seismic resolution is investigated.

Signal-to-noise ratio must be considered for a good matching. Noise attenuation is affected by multiplicity, muting and frequency bandwidth. Imaging processes can also greatly influence the final signal-to-noise ratio. For example, a small DMO aperture can eliminate some coherent noise. On the other hand, a spike or an anomalous amplitude event can be spread out in a large region by using a big migration aperture.

When 4D analysis is carried out over subtraction volumes, the amplitude and the shape of the signal become extremely

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important. An important role in determining the shape and amplitude of the seismic pulse is played by muting, deconvolution, offset distribution, and stacking velocity. Again, imaging algorithms have to be taken into account. Several possibilities of how to deal with amplitudes have to be considered.

PRELIMINARY RESULTS

The presence of a cap of gas can increase the absolute amplitude value at the top reservoir reflection. For a thin gas cap, the amplitude value at the top reservoir should not change. On the other hand, for a thicker gas cap some changes are expected. The absolute amplitude value at the bottom reservoir is expected to remain the same. Based on these premises, the ratio of top to bottom amplitude increases where a gas cap exists. Therefore, the difference between the ratios computed on legacy and monitor may be a good approximation for monitoring the gas cap formation. In order to illustrate the influence of the seismic processing on time-lapse analysis, we have started studying the low influence case.

Working with relative amplitudes is supposed to be a processing independent procedure. We applied this procedure in both cross-equalized volumes, namely, New and New-rep. The final maps of ratio differences ARE presented at figures 2 and 3. The red zone indicates the area where secondary gas cap could be appeared. Notice how this area has been shrunk after the seismic reprocessing. Despite of the apparent good equalization, seismic traces have shown events with different resolution in disappeared red areas. The most probable hypothesis is that imaging algorithms, such as stacking, DMO, and migration could generate the main differences in seismic resolution. A small change in the seismic velocity field could bright or dim a seismic reflection after stacking. Using coarse grids requires more effective anti-aliasing filters, whose action causes similar effects.

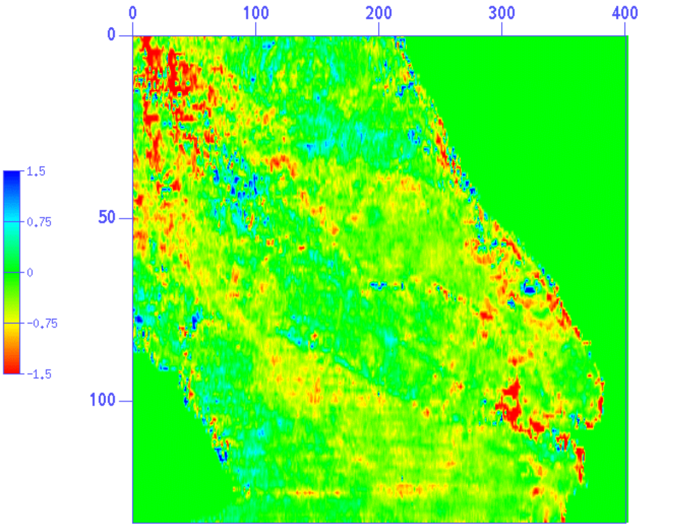

Figure 2. Map of difference of amplitude ratios computed without reprocessing.

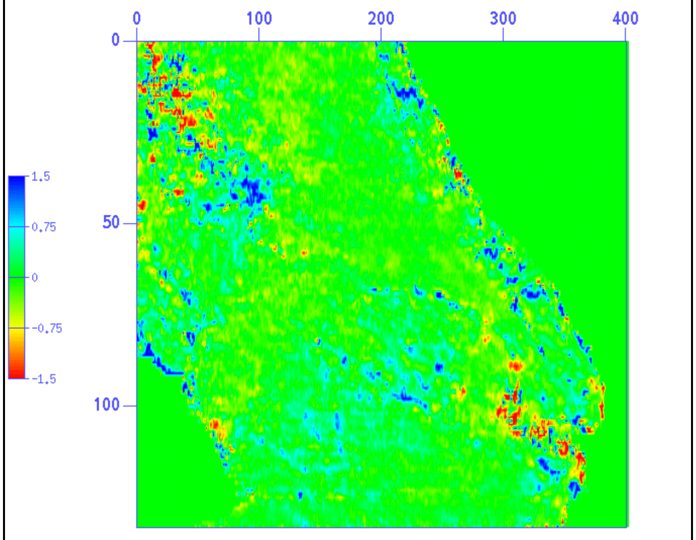

Figure 3. Map of difference of amplitude ratios computed after reprocessing data.

The map generated without reprocessing, figure 2, is impressed with some acquisition marks. Alignments in south-north and east-west directions are related to the legacy data. While marks with 33 degrees of azimuth are due to the monitor data. The acquisitions marks are smaller in reprocessing map, see figure 3.

CONCLUSIONS

We have been started a criterious analysis of the influence of seismic processing on Marlim field time-lapsed studies. Several aspects, like recovered amplitudes, signal-noise ratio, and seismic resolution, have been analyzed. Preliminary results have indicated a strong influence of seismic processing over the monitoring maps. Some differences on imaging process application could have affected the preliminary results.

Monitoring maps generated form reprocessed data have been little impressed by acquisition marks. These maps are cleaner and more reliable, that permits a more confident reservoir monitoring.

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