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4D Seismic in Brazil: Experiences in Reservoir Monitoring

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Abstract

Many technical-economic indicators characterize E&P activities. Two among these indexes are of utmost importance, namely exploratory success and recovery factor. In E&P project management analysis, net present values and expected monetary value of projects are commonly used.

In most cases, however, despite the significant amount of capital investments made in new E&P technologies, exploratory success and recovery factor still fail to surpass the long targeted 50% level.

Considering that some reasons for are related to geosciences uncertainties, seismic technologies have historically played a major role in helping the oil industry reduce such geosciences uncertainties and improve E&P indicators.

The use of time-lapse or 4D seismic technology enables the oil industry to improve their E&P activities related to reservoir management. In addition to updating the 3D geological and flow models, new 4D seismic information helps not only to enhance reservoir characterization, but also to reveal potential exploratory upsides and to monitor field production.

This work aims to describe 4D seismic technology experience in Brazil during the last 12 years of studies and applications in Brazilian petroleum fields. Fazenda Alvorada and Alto do Rodrigues, onshore Reconcavo and Potiguar basins were the pioneer 4D seismic pilot studies in Brazil, having started in 1994 and 1998, respectively.

4D experiences in Brazil can be divided in three main phases: (1) technical and economic feasibility studies and onshore pilot projects; (2) applied research projects (PRAVAP - IOR Strategic Research Projects) and (3) offshore deepwater projects.

During this period, we have developed a process workflow with 15 phases from the identification of potential new 4D seismic projects (VOI analysis) through the *a posteriori* quantification of the return on investment (ROI).

Three case histories of 4D seismic experiences in Brazil will be presented: two onshore fields projects with secondary

recovery using steam injection and a deepwater oilfield project with water injection (Marlim Complex).

The challenge of this deepwater 4D seismic survey project was to acquire seismic data over 1,520 km² in a heavily obstructed oilfield production area. Currently, Marlim Complex produces more than 700,000 bopd from 9 fixed production platforms.

Besides platforms, other types of obstructions have been found in the area such as storage and offload vessels, drilling rigs, tankers, pipe laying barges, marker buoys, and general marine traffic in and out of the area. These fixed and dynamic production equipment pieces accounted for 40 operational obstructions faced during the project.

Seismic quality control was so relevant for this project that, for the first time in Brazil, we caused six different FPSOs to be rotated to align with the seismic vessel which towed 10, 6 km-long cables. This was done to reduce the holes in seismic imaging around the production platforms in view of the importance attributed to the reservoir characterization in these areas.

The strong cooperation and communication between the seismic vessel and platform crew members were critical to acquire data as close to these obstructions as possible and to plan seismic acquisition data recording in between oil offload operations. The critical marine logistics involved in this project caused it to become, by far, the most complex seismic operation ever performed in Brazil.

The seismic data processing of Marlim Complex project started with 152 terabytes of raw data and was carried out both, on-board and in Rio de Janeiro. However, during some of the seismic processing key steps, such as multiple attenuation and migration, processing centers in Houston and Gatwick were also involved, so as to speed up the project timing schedule. This caused 12,000 CPUs (9,000 in Houston and 3,000 in Gatwick) to be simultaneously involved in the peak phase of the processing stage.

3D and 4D seismic interpretations of Marlim Complex are being carried out at the present moment.

Introduction

To date, 1,300,000 km of 2D lines seismic and more than 400,000 km² of 3D seismic programs have been completed in the 29 sedimentary basins in Brazil (the total onshore and offshore area of sedimentary basins in Brazil amounts to nearly 8,700,000 km²).

4D seismic technology is still in its initial phase in Brazil. We can enumerate the following reasons for that: most of our mature fields are located in onshore basins and major