# Synthetic Modeling of Seabottom Node Acquisition over the Libra Field

Carlos Montana, Franck Le Diagon, and Tim Bunting, Schlumberger; Roberto Dias, Petrobras



## Abstract

This paper describes a synthetic seismic modeling effort over the Libra field conducted by Schlumberger, in collaboration with geophysicists from the Joint Project Team (JPT) of the Libra consortium, to optimize acquisition parameters for the planned new seismic acquisition. The effort included the modeling of node and towed streamer geometries and generation of multiple seismic images for comparison purposes, including regular and mirror migrations, images of full- and down-sampled node geometries, and comparisons against images of narrow-azimuth streamer geometries. Based on the results of this study, the acquisition template was finalized and used in the invitation to tender for the acquisition project.

## Introduction

The Libra field is located in the presalt province of the BMS 11 block of the Santos basin, offshore Brazil (see Figure 1). The field was discovered in 2010 and has generated global interest because of its size and volume estimates. If estimations are correct the field will be one of the largest finds to date and the largest find since the Cantarell discovery in 1976. Production rights were awarded to a consortium of five companies in October 2013 (Petrobras, Shell, Total, CNPC, and CNOOC). As part of the exploration and development plans the consortium proposed to acquire new 3D surface seismic over the full field (approximately 1,500 km$^2$).

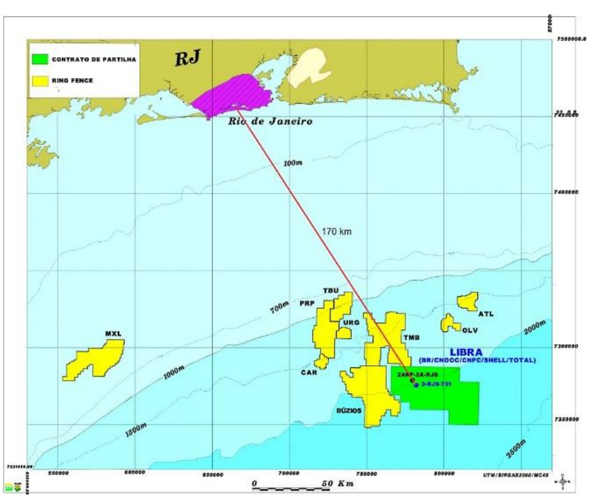


**Figure 1. Libra field location.**

In early 2014, a synthetic modeling study was initiated to evaluate a sparse-node seismic measurement over the field. The goals of the study were threefold:

1. Analyze and quantify the expected uplift of node geometries over the existing narrow-azimuth towed streamer measurement.
2. Understand the optimum sampling parameters of a node geometry including node separation, source separation, and maximum offset.
3. Compare upward (conventional) with downward (mirror) migration and the impact of each migration on the shallower and deeper areas seismic quality.

## Method

An acoustic model (compressional velocity (Vp) and density) was created by Petrobras (the consortium's operator) and provided to Schlumberger for the purposes of the synthetic seismic modeling study (Figure 2). Using this model, pressure and vertical particle velocity data were synthesized for a node geometry, and pressure-only data were synthesized for a narrow-azimuth towed streamer geometry. The full 2-way wave equation was used to extrapolate the seismic wavefield through the model. For both datasets, the maximum frequency modeled was 31 Hz. The node data were modeled with a slightly longer record length to allow for mirror migration. For the node data, to benefit from the efficiencies associated with the sparse receiver sampling, reciprocity was assumed, i.e. shooting from the sparsely sampled seabed receivers to the densely populated surface sources.

Node geometry:

- 400 m × 400 m receiver grid
- 25 m × 25 m source grid
- 10,000 m × 10,000 m maximum offset

Streamer geometry:

- Narrow azimuth
- 10 × 8,100 m streamers at 100-m streamer separation and 9-m depth
- Two sources at 50-m separation and 6-m depth; each source firing once every 50 m inline

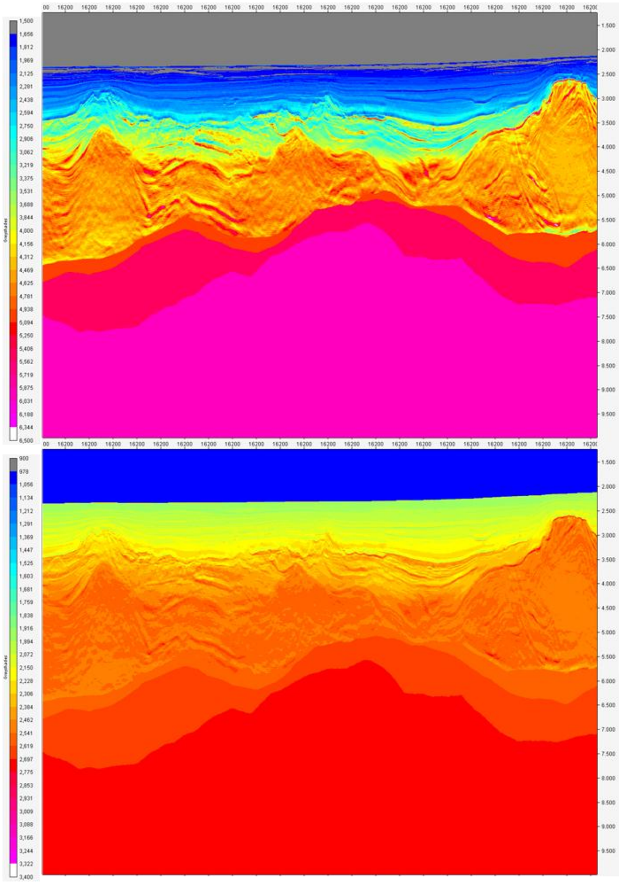

**Figure 2. Cross section of model provided by the Libra field consortium JPT; Vp (top) and density (bottom).**

Each dataset was processed through to final image. For the node data, to understand the impact of source and receiver sampling and maximum offset, multiple images were generated using subsets of the modeled dataset. Furthermore, for the node data, the P (pressure), and Vz (vertical component of velocity) measurements were used to perform wavefield separation. The resulting upgoing wavefield was migrated with the model supplied, whereas the downgoing wavefield was migrated with the mirror model (water column extended vertically by the node depth and nodes positioned at the new sea surface).

Node processing workflow:

- Wavefield separation in the (3D) tau-pq domain
- Reverse time migration (RTM) of the upgoing wavefield using the original model
- RTM of the downgoing wavefield using the mirror model

Towed streamer processing workflow:

- RTM using the original model

The node geometry was additionally down-sampled to finalize on the optimum geometry in terms of node sampling, shot sampling, and maximum offset. The following node geometries were also imaged (each one with 50 m × 50 m shot spacing):

- 400 m × 800 m node geometry with 8 km of maximum offset
- 400 m × 800 m node geometry with 10 km of maximum offset
- 400 m × 400 m node geometry with 8 km of maximum offset

**Results**

Figure 3 details a comparison of the migration of the upgoing and downgoing wavefield. The upgoing wavefield was migrated with the regular model, whereas the downgoing wavefield was migrated with the mirror model. In deep water, the asymmetric ray-path of a node layout results in very inconsistent illumination of the water bottom and near-water-bottom events. The illumination cone of each node increases with depth below the water bottom and, for shallow events, the illumination cones, from adjacent nodes, do not overlap, resulting in zones in which the seismic response is not measured. This is resolved with the migration of the downgoing wavefield as demonstrated in Figure 3. The downgoing wavefield is migrated with a perturbed model (mirror model) which complies with the first-order multiple ray path. Note the poor sampling of the water bottom on the top image (regular migration) visualized as a migration impulse response. This is resolved with the bottom image (mirror migration).

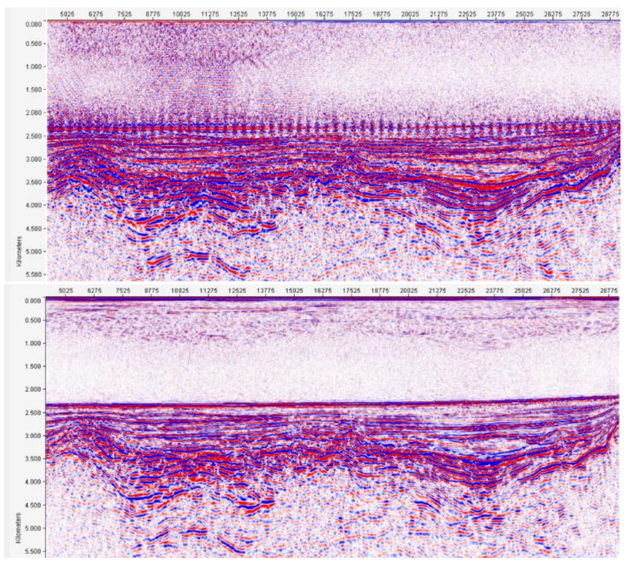

**Figure 3. Evaluation of mirror migration to improve shallow imaging. Top: Upgoing wavefield migrated with the regular model. Botton: Downgoing wavefield migrated with the mirror model**

Figure 4 details a comparison of the narrow-azimuth towed streamer geometry and the downgoing wavefield of the undecimated node geometry migrated using the mirror model. As highlighted in this comparison, the node image has better shallow resolution of the near surface and more consistent illumination of the presalt reflection. The deepest reflector had a constant impedance contrast in the input model, serving as an excellent reference for quality control of the final images.

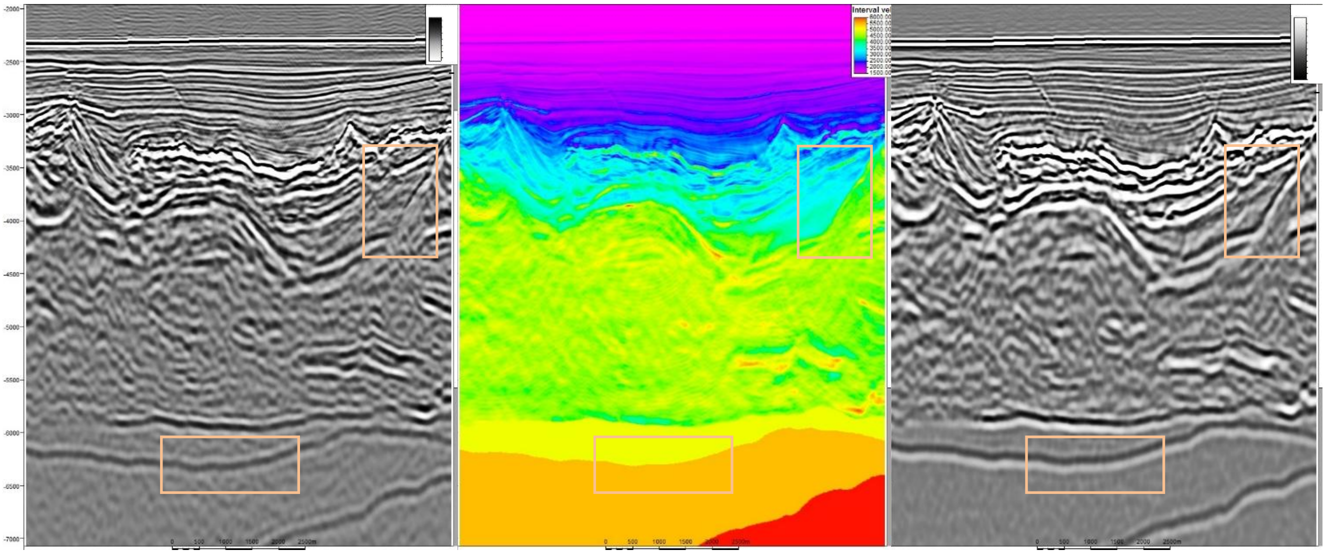

**Figure 4. Comparison of an image of a narrow-azimuth towed streamer geometry (left) and the undecimated node geometry (right). Velocity field in the middle for reference.**

Figures 5 and 6 summarize an effort to understand the optimum node geometry. Figure 5 compares a mirror migration image with a 400 m × 400 m node grid with a mirror migration image with a 400 m × 800 m node grid. Figure 5 compares a mirror migration image with an 8,000-m maximum offset with a mirror migration image with a 10,000-m maximum offset. While there are some small differences the down-sampled images in general preserve the fidelity in the image.

## Conclusions

In this paper we have presented a synthetic seismic model effort to understand the uplift associated with a node measurement and to optimize the node geometry. The work provided confidence that a node solution using mirror migration would deliver uplift on the existing narrow-azimuth towed streamer measurement. Based on this work the Libra consortium has invited node contractors to tender for acquisition over the Libra field.

## Acknowledgments

Petrobras and Schlumberger acknowledge the Libra consortium members for their permission to share the work and their technical input during the project. We would like to thank the following members of the Libra field JPT: Wenceslau Gouveia of Shell; Christian Deplante of Total; and Sergio Araujo of Petrobras, who, among many others, helped in the development of this work. A special thanks to Carlos Cunha, Cláudio Guerra, and Gilberto Lima from Petrobras' geophysical technology group and also to Roberto Dittz and Bernardo Radefeld from the marine seismic acquisition group.

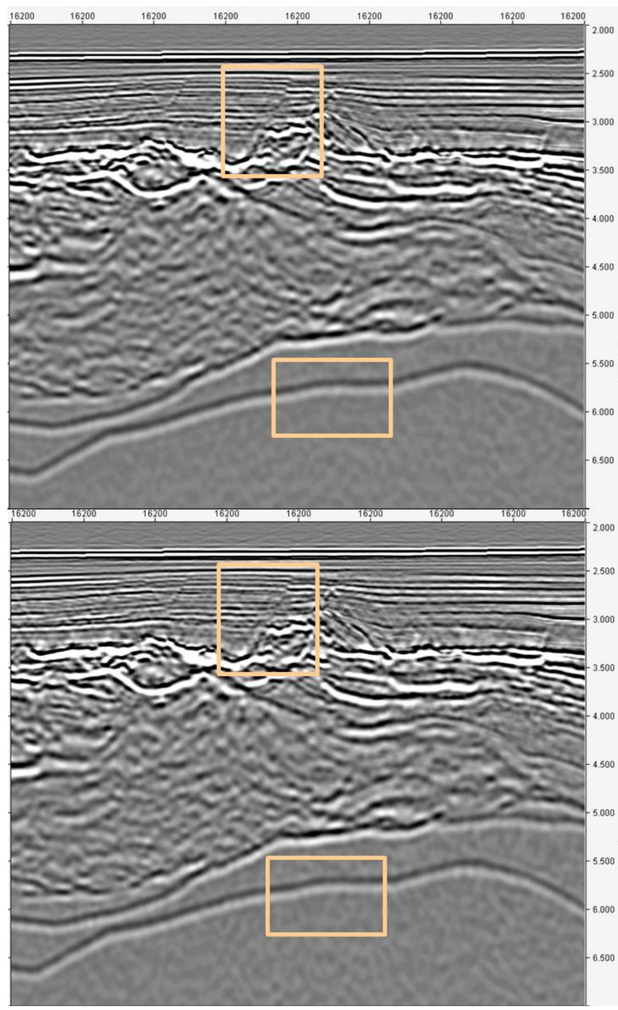

**Figure 5. Evaluation of node density. Comparison of 400 m × 400 m(top) versus 400 m × 800 m (bottom) node sampling.**

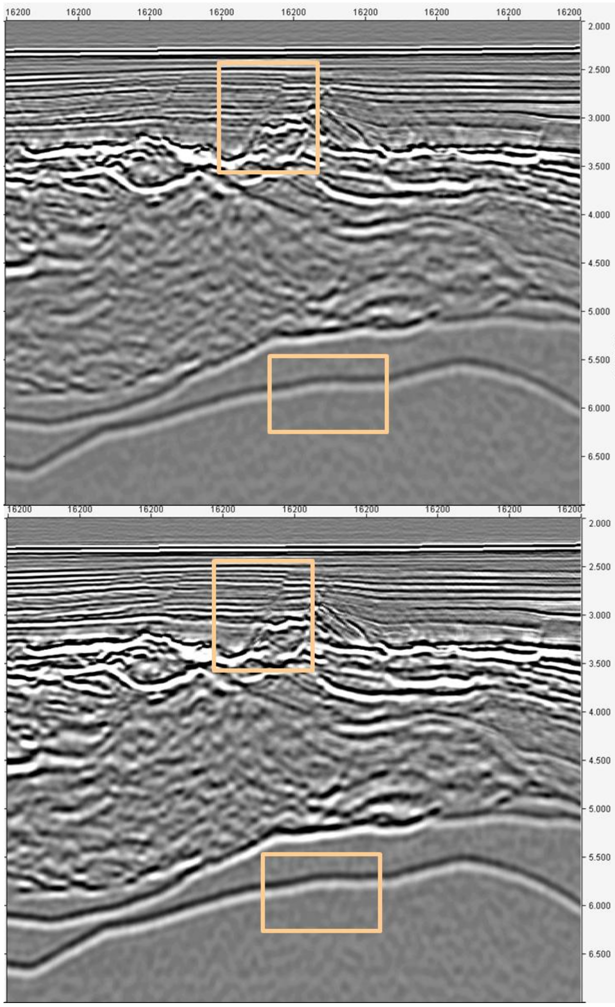


**Figure 6. Comparison of images of the undecimated node data (bottom) and the node data limited to an 8,000-m maximum offset (top). The differences between the two datasets, even at the presalt target level, are very subtle.**