Offshore solutions: Brazil broadband case study

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Abstract

This paper presents broadband seismic data acquired in the deep waters of the Santos Basin, using CGG's new curved variable depth streamer technology. A descriptive and illustrated account has been carried out from the multi-client Phase 6-B survey displaying the benefits of broadband data for seismic interpreters. Phase 6-B is located offshore in the Santos Basin and covers the post-salt Atlanta and Oliva discoveries. It extends over the Phase 6-A conventional survey area, which contains the multi-billion barrel oil field Libra.
A shallow to deep approach is taken through the dataset demonstrating the benefits of broadband seismic data for the end-user. Comparison examples are taken from Phase 6-B (broadband, variable depth streamer data) and Phase 6-A (constant depth streamer).

Introduction

Pre-salt reservoir targets have been a major focus for offshore exploration in the Santos Basin. With the aid of broadband seismic, an increase in low and high frequencies help the interpreter to see a 'true' seismic signature without the presence of unwanted side-lobes and therefore provides significant details about the geology. A broader frequency spectrum allows a seismic wavelet to represent a more genuine signature of geological facies.
The following examples have been used from the Phase 6-A and 6-B surveys to see the comparison and effects of broadband variable depth streamer acquisition and processing. Both datasets have been processed using Kirchhoff PSDM algorithms with the difference that Phase 6-A conventional data have benefitted from a full anisotropic PSDM sequence while the Phase 6-B dataset is a fast-track isotropic volume.

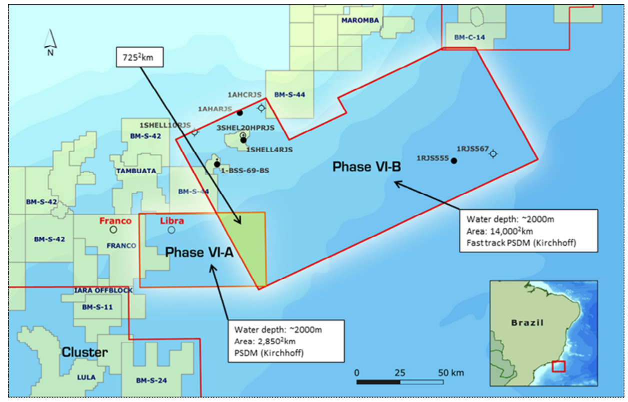

Figure 1: Phase 6-A and Phase 6-B surveys located offshore Brazil in the deepwater Santos Basin.

Regional interpretation

Similar sequences and stratigraphy can be seen in the broadband fast-track data as seen in CGG's Cluster datasets to the south west, which cover the giant Lula Field. Beneath the evaporites we see clear syn-rift growth packages where sediments thicken into extensional fault planes (Figure 2). Also, a differentiation of two distinct syn-rift packages is seen at depth. A very promising post-rift sag phase is also present, identified by uniform and parallel reflectors below the evaporites. The recognition of this sequence is key to establish if the primary reservoirs of microbial carbonates are present within this section.

A thick sequence of evaporites extends laterally across the basin, where mobile halite is a major controlling factor to the post-salt topography and deposition. Directly above the evaporites in the post-salt, igneous intrusives are present. These are represented by an increase in impedance and high amplitude reflectors with wing-like geometries, typical of intrusives such as sills and dykes. Small scale listric fault and slump features are identified within the post-salt with channel systems located above. Chaotic reflectivity is established in the post-salt indicative of deep water turbidites, as seen to represent the primary reservoir for the Atlanta Discovery.

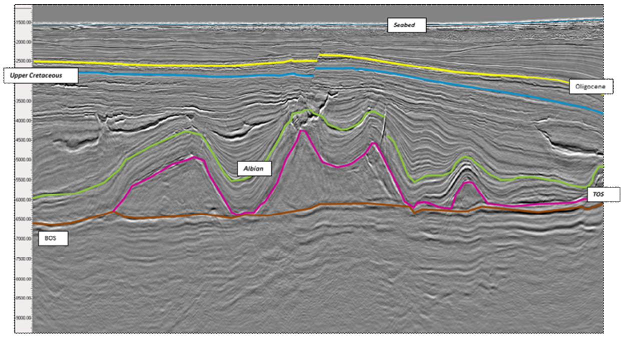

Figure 2: A regional seismic line taken from Phase 6-B indicating stratigraphic intervals within the section.

Broadband wavelet for interpretation

By introducing higher frequencies, the central peak wavelet becomes sharper and more pronounced while an increase of low frequencies results in the amplitude of side-lobes being reduced.

A comparison of conventional and broadband data is taken from the post-salt, with particular focus on high amplitude volcanic intrusives (Figure 3). A wiggle seismic display has been added to better see the comparative effect of side-lobes and noise. Highlighted features a, b and c display clearly the positive differences of broadband processing. Side-lobes and tuning effects displayed by the wiggle traces are dramatically reduced and near absent, an effect of the increased bandwidth. A more genuine stratigraphic seismic signature is established without the interference of the wavelet side-lobes.

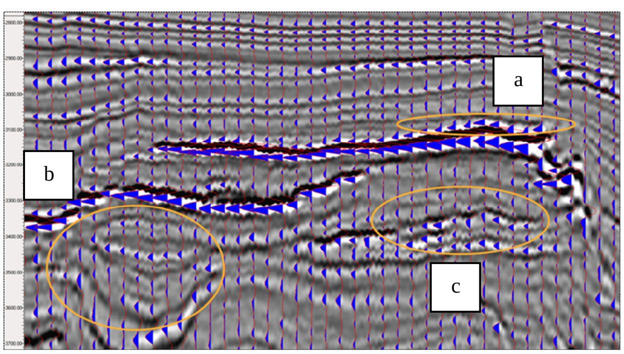

Figure 3a: Conventional seismic line with wiggle trace overlays

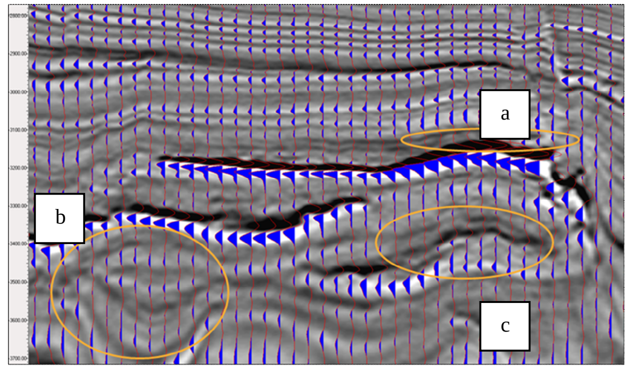

Figure 3b: Broadband fast track seismic line with wiggle trace overlays

Broadband benefits for post-salt interpretation

The post-salt of the Santos Basin holds a great amount of hydrocarbon potential, with many discoveries and fields found in post-salt reservoirs, these comprise of channel sands and deepwater turbidites.

Using a curved variable depth streamer profile, broadband imaging provides benefits to the most recent deposits in the post-salt stratigraphy. Figures 4a and 4b are comparative sections taken across dense faulting above the crest of a salt diapir. Better definition of fault planes are visible on broadband data without the interference of side-lobes. A high level of detail is present portraying a series of smaller faults and fault splays.

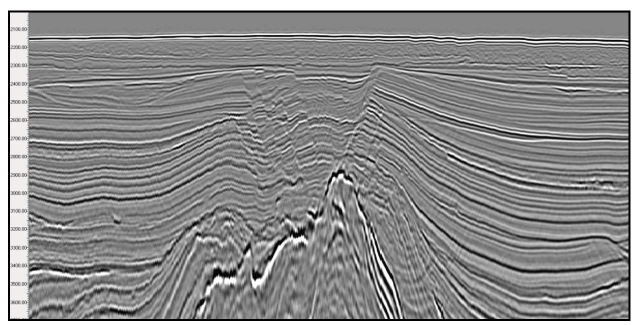

Figure 4a: Conventional seismic line of crestal faults related to diapirism.

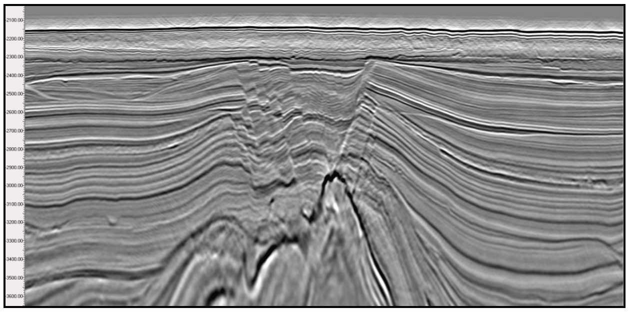

Figure 4b: Broadband fast track seismic line of crestal faults related to diapirism.

Figures 5a and 5b highlight the great detail that broadband data can display. A simple petroleum fairway can be established from the attention to the detail of the stratigraphy where reservoir and seals can be seen. The image displays two channel features with clear seismic reflections corresponding to the base and top channel sands. The top of the channel sand facies can be identified by an increase in impedance, a strong black reflector, with a contrasting decrease in impedance at the base, indicated by a soft white reflector. The channel sand facies have a subtle, darker due to the background low frequency content which allows the interpreter to pick out facies changes. The sand facies are trapped within the channel structure with predominantly shale facies overlaying, typically found within proximal channel systems.

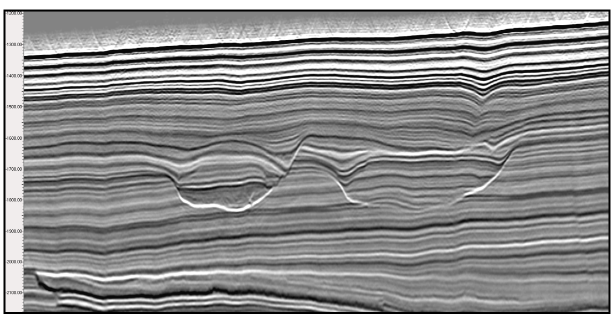

Figure 5a: Broadband fast track post-salt channel features.

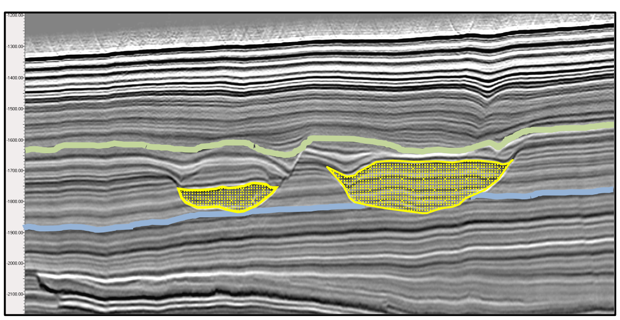

Figure 5b: Broadband fast track post-salt channel features with interpretation.

Atlanta Discovery case study

Figures 6 is a broadband fast-track seismic line taken through the Atlanta Discovery where structure and stratigraphy can be seen. A direct oil-water contact can be easily identified within the Tertiary section and chaotic reflectivity represents the turbiditic reservoir facies. Extensional faults can be identified with the reservoir potentially being compartmentalised. A closer look into the oil-water contact can be seen in Figure 7 where the broadband data highlights an increase in impedance at the contact. Also a great amount of detail can be interpreted within the structures above the contact and from the adjacent faults.

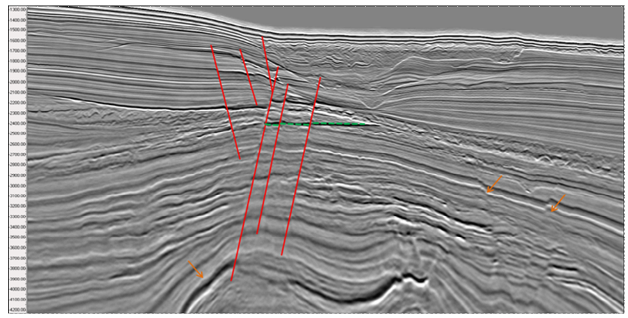

Figure 6: SW-NE seismic line through the Atlanta Discovery.

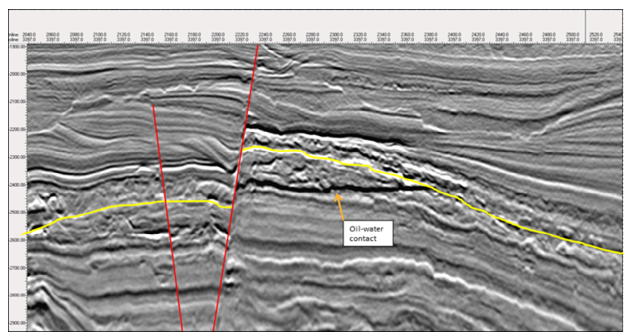

Figure 7: A closer view of the Atlanta Discovery oil-water contact.

Interpretation was carried out at top reservoir level with a direct amplitude extraction, seen in Figures 8a and 8b. The amplitude attribute highlights definitive structure with additional faults becoming more apparent, a result of the increase in high frequencies. A number of splays can be seen to extend away from a main fault trending north-east to south-west, with a number of primary and secondary fault intersections. Hydrocarbon-filled reservoir sands are highlighted by the bright amplitude anomalies, which clearly show two main adjacent accumulations and compartmentalisation by large scale fault systems.

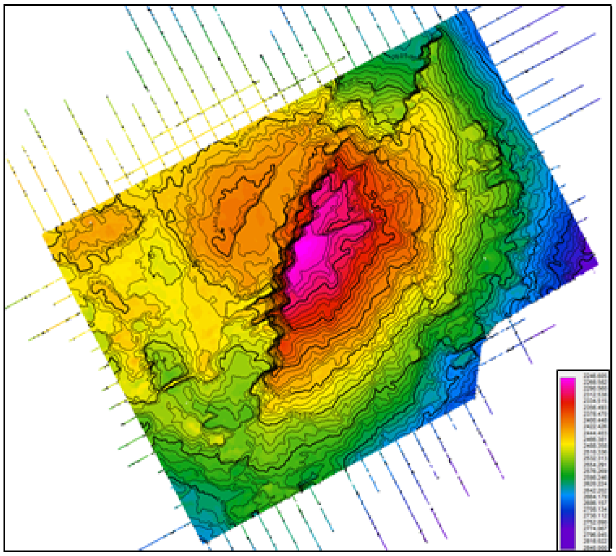

Figure 8a: Depth structure map at top reservoir

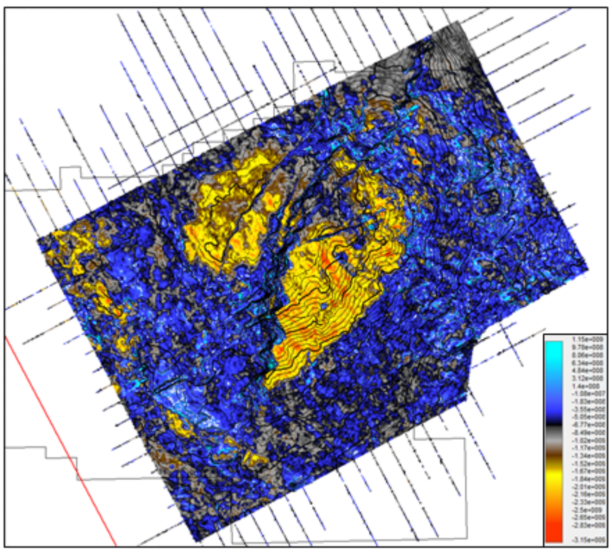

Figure 8b: Depth structure map at top reservoir

Conclusions

The accuracy and efficiency of seismic data interpretation is greatly enhanced when using broadband seismic data. We can list the main benefits as follows:

- 'True' seismic signature of geological formations.
- Stratigraphy and subtle features are better defined
- Structures and fault planes are better visualised without the interference of side-lobes.

New opportunities and refinements to existing geological models can be established, all participating in a better understanding of petroleum systems.

Acknowledgments

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