SDRs or presalt synrift graben? – Insight from an integrated case study of presalt reflectors in Campos Basin, offshore Brazil

Quincy Zhang, Gary Rodriguez, Hao Xun, Duncan Bate and James Keay, TGS; Michael R. Hudec, Bureau of Economic Geology, The University of Texas at Austin; Jonathan Watson, Bridgeporth Ltd*

Summary

Seaward-dipping reflectors (SDRs) represent flood basalts rapidly extruded during either rifting or initially subaerial sea-floor spreading (Jackson et al., 2000). Where high-quality geophysical data is not available, SDRs can be easily confused with a half graben, when both have reflections dipping seaward and both are near to the Continent-Ocean Boundary (COB). Differentiating SDRs and a half graben would have a huge impact to hydrocarbon exploration – a half graben in a rift basin is one of the major exploration targets but SDRs usually indicate that there is no exploration potential. We investigate a high-resolution 3D dataset in the Campos Basin, reprocess the dataset with gravity constraint and interpret a presalt graben system where previous workers interpret as SDRs.

In this paper we present

- Methodology for reprocessing Offshore Brazil Olho de Boi 3D survey acquired near the COB;
- Salt modeling;
- Gravity modeling and gravity constrained presalt velocity update;
- Reinterpretation of the presalt reflectors.

The reprocessing workflow is specially designed to image the presalt section. The interpretation based on the new 3D image, gravity inversion and borehole correlation suggests a large graben system in the center of the 3D survey. The improved presalt seismic images and the new interpretation of presalt graben systems will greatly help explorationists to analyze presalt sediment architecture and petroleum systems.

Introduction

The Campos basin, which is located along the passive margin of Brazil, is part of the East Brazil rift system which formed in the Jurassic–Early Cretaceous and led to the opening of the South Atlantic (Meisling et al., 2001). Significant discoveries from presalt areas in Campos and other Brazilian basins draw great attention to this new play. We revisit a presalt area which had recently been interpreted as SDRs by Norton et al. (2016). With newly acquired and processed high-quality 3D seismic data, we suggest that the presalt sediment package previously interpreted as SDRs is instead a graben filled with synrift seaward-dipping sediments.

The reinterpretation effort includes two interactive processes – seismic depth imaging with better geological constraints including gravity modeling, and geological interpretation with improved seismic data. An alternative anisotropy model was tested assuming larger anisotropy values between the base of salt and the base of synrift derived from gravity studies. In order to maintain flat gathers, the velocities are expected to decrease when anisotropy increases, therefore the velocities become more compatible with sediment velocities (Figure 1) within the sedimentary section estimated by gravity modeling.

Key technologies, including broadband processing, Tilted-Transverse Isotropic (TTI) model building and imaging, were applied to the processing of the 3D survey. In the following sections we will briefly discuss salt modeling and gravity modeling, and then will focus on the interpretation of the presalt reflectors.

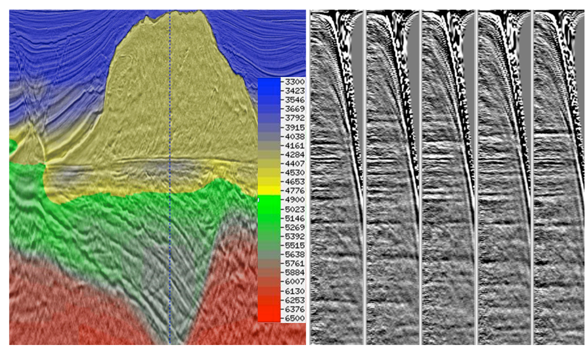

Figure 1: Sediment velocities constrained by gravity modeling. Gathers are flat in this area.

Salt modeling

Because our target is a presalt package, salt modeling is critical for this effort. Detailed salt interpretation including local scenario tests is conducted and multiple iterations of migrations and tomography are done to obtain an accurate salt model. During the salt modeling process, we routinely evaluate subsalt images, especially the base of the autochthonous salt, to make sure the subsalt image is geologically correct. For example, if we see any undulations of base of salt we revisit the salt model to analyze if there are any geological reasons which cause the undulations. If we find that the undulations are caused by model issues, we fix either the salt model or the sediment model to ensure that the model above the presalt section is correct.

Gravity modeling

Gravity modeling is done to constrain the presalt velocities. In the gravity modeling process, merged 2D and 3D marine gravity data are utilized to assist imaging of the presalt structure, seismically interpreted depth horizons from seabed to base salt are used to construct a 3D depth volume, and density values are used to populate the depth volume and calculate the gravity response. We compare the response of this volume to the acquired marine gravity dataset (Figure 2) and observe the differences. These differences are then input to a gravity inversion. The inversion, run iteratively, produces a top basement depth surface (Figure 3) to compare against the seismic volume, and then use this top basement surface as a bottom mask for the velocity update. A number of interesting features are noted giving further insight to the presalt geology we describe in the next section.

Presalt interpretation

The base of presalt (Figure 4, Figure 5) and the base of autochthonous salt (Figure 4, Figure 6) are mapped and analyzed. We can see that the base of autochthonous salt horizon (Figure 6) is very smooth on the NW side of the survey and becomes more rugose to the SE. From seismic cross sections (Figure 4) we can see that from NW to SE the base of autochthonous salt changes from trough-dominated, to peak-dominated, and finally to rugose chaotic. We interpret this trend to indicate that salt was deposited on postrift slow-velocity sediments to the NW, on synrift high-velocity sediments in the middle of the survey, and directly on high velocity oceanic crust to the SE.

We compute the thickness of the presalt sediments (Figure 7) from the base of autochthonous salt and the base of presalt. The base of presalt surface map (Figure 5) and the thickness of presalt sediments map (Figure 7) show that a major graben trends NNW, and that sediment thicknesses in the graben exceed 4000 m over a large area. Because this graben is under salt, hydrocarbon traps can be very large. The biggest growth package is on west side of the graben, producing seaward sediment dips that give the appearance of an SDR sequence. However the narrowness of the basin, the apparent termination of reflections against a steep fault, and the existence of a reflection-free basement block just downdip all lead us to reject an SDR interpretation in favor of a graben model.

We also correlate units in the graben to the nearby Pão de Açúcar well, using a regional 2D seismic grid and the 3D seismic data (Figure 8). The Pão de Açúcar well is the third discovery in BM-C-33 block after Seat and Gávea, and found a presalt hydrocarbon column of 500 m, one of the thickest to date in Brazil. The seismic data clearly show that the presalt sediments discovered in Pão de Açúcar well can be correlated to the graben system observed in the 3D data.

Conclusions

Based on interpretation of a new high quality 3D seismic data, gravity inversion and a well-2D-3D tie, we conclude that a package of presalt reflections that could be confused with SDRs is instead a presalt synrift graben. Further study of the new 3D data will greatly improve the industry's understanding about the exploration potential in this area and will likely open a new territory for hydrocarbon exploration.

Acknowledgements

The authors would like to thank Cristina Reta-Tang and Henrik Roende for their contributions; Ron Steel for his advice about rift basin; Connie VanSchuyver for reviewing the manuscript; and TGS management for permission to publish this paper.

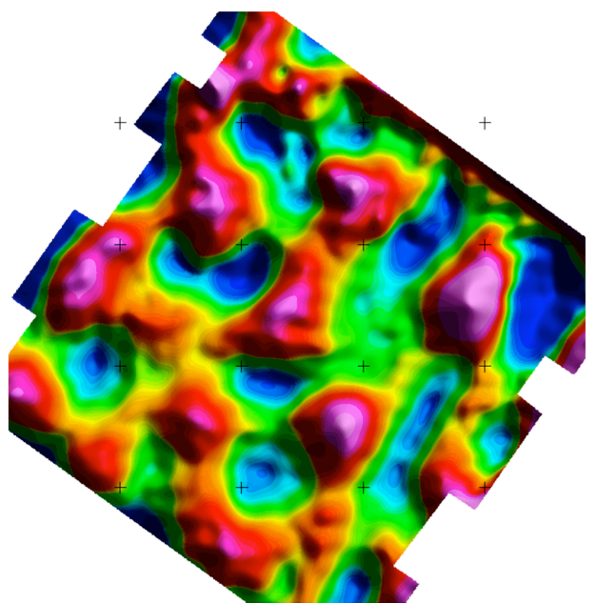

Figure 2: A filtered version of the 3D marine gravity survey.

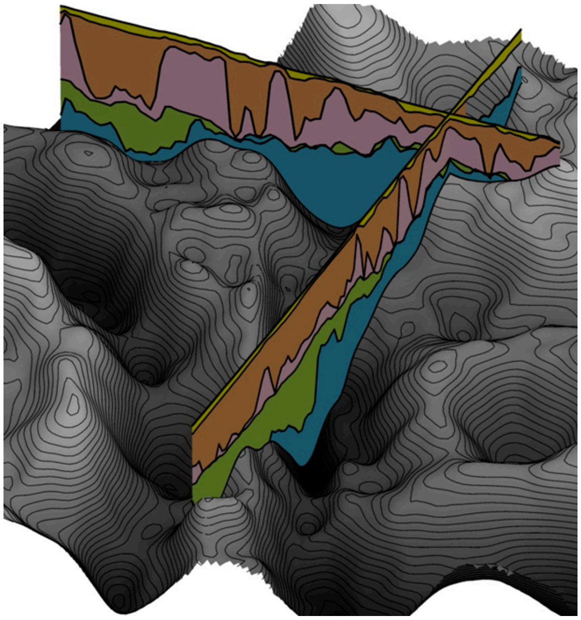

Figure 3: Top basement map with 2 cross sections, produced by gravity inversion.

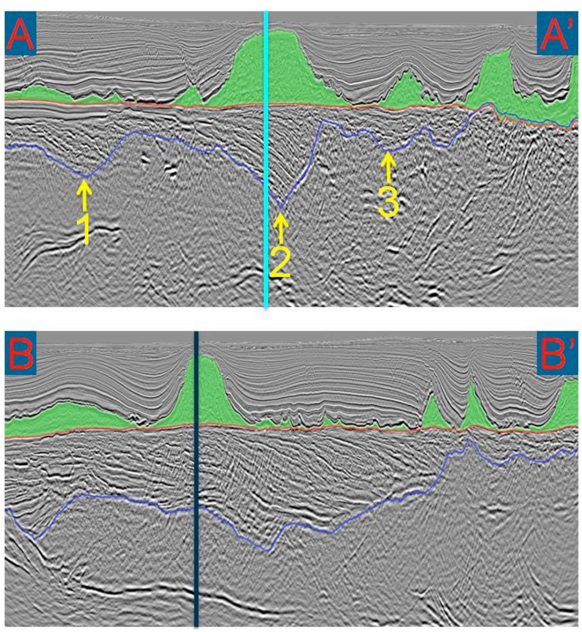

Figure 4: Base of autochthonous Salt (red) and base of presalt (blue) on two seismic sections. The locations of the seismic sections are shown in Figure5, 6 and 7.

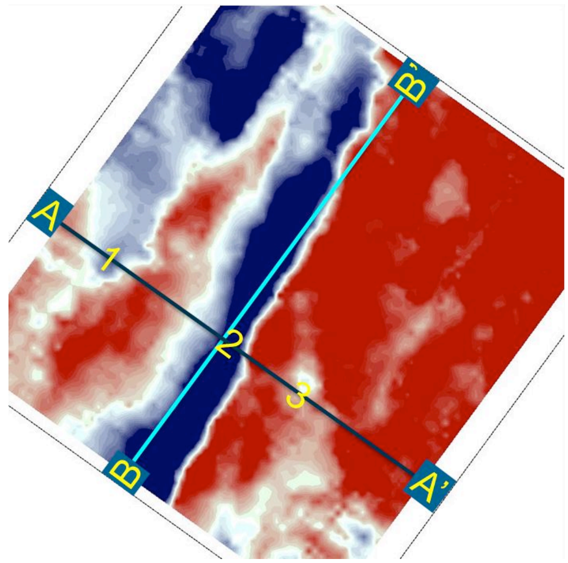

Figure 5: Base of presalt surface map. The map shows that a major graben (blue area in the center of the survey) trends NNW.

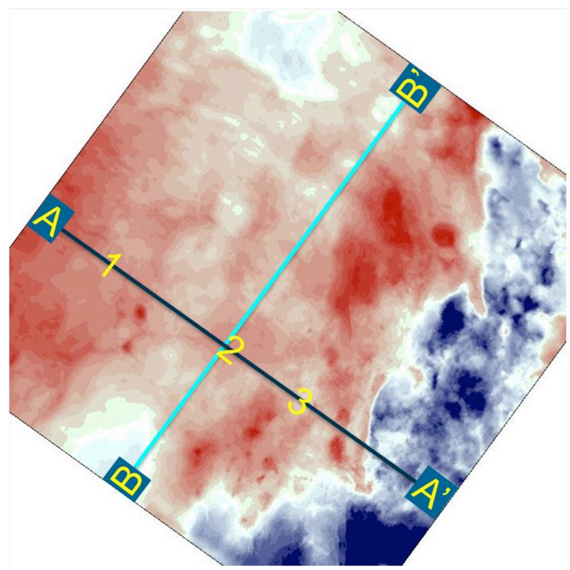

Figure 6: Base of autochthonous salt surface map. It shows that the surface is very smooth on the NW side of the survey and becomes more rugose to the SE.

SDRs or presalt synrift graben?

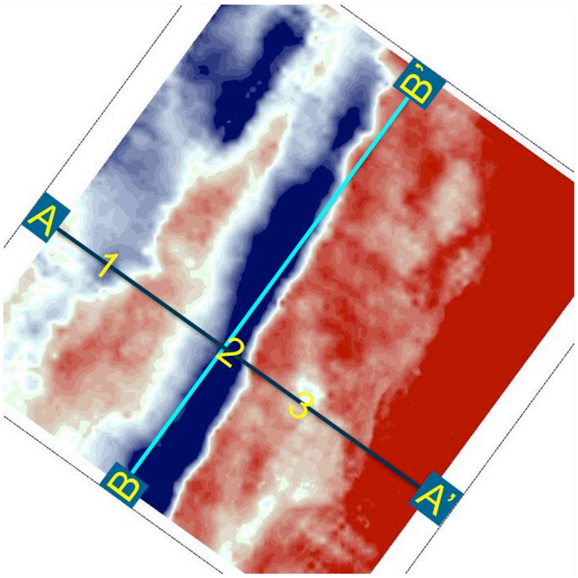

Figure 7: Total thickness of presalt sediments. It shows that a major graben (blue area in the center of the survey) trends NNW, and that sediment thicknesses in the graben exceed 4000 m over a large area.

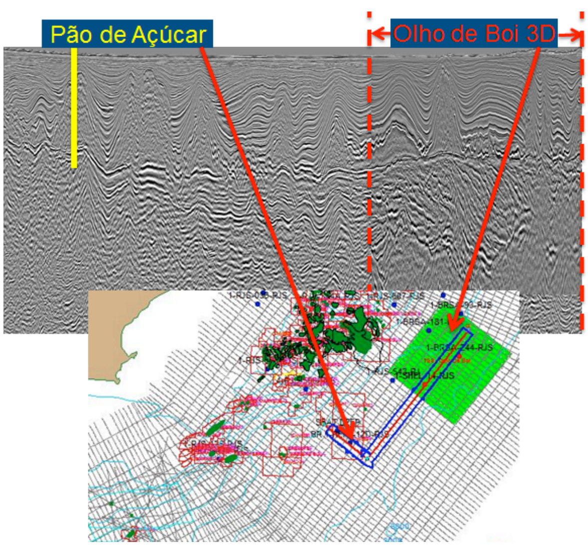

Figure 8: Well-2D-3D correlation. A presalt sediment package can be correlated continuously from Pão de Açúcar well to the graben in the 3D area.

EDITED REFERENCES

Note: This reference list is a copyedited version of the reference list submitted by the author. Reference lists for the 2017 SEG Technical Program Expanded Abstracts have been copyedited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

REFERENCES

Jackson, M. P. A., C. Cramez, J.-M. Fonck, 2000, Role of subaerial volcanic rocks and mantle plumes in creation of South Atlantic margins: Implications for salt tectonics and source rocks: Marine and Petroleum Geology, **17**, 477–498, http://doi.org/10.1016/S0264-8172(00)00006-4.

Meisling, K. E., P. R. Cobbold, V. S. Mount, 2001, Segmentation of an obliquely rifted margin, Campos and Santos basins, southeastern Brazil: AAPG Bulletin, **85**, 1903–1924, https://doi.org/10.1306/8626d0a9-173b-11d7-8645000102c1865d.

Norton, I. O., D. T. Carruthers, and M. R. Hudec, 2016, Rift to drift transition in the South Atlantic salt basins: a new flavor of oceanic crust: Geology, **44**, 55–58, http://doi.org/10.1130/G37265.1.