Submission code: 6ZXXNRQ8ZR

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Reprocessing of land seismic data from the Barreirinhas Basin, Brazil.

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Abstract

The Barreirinhas basin is located in north-eastern Brazil, specifically along the Brazilian Equatorial Margin on the coast of the state of Maranhão. It is a well-known region due to its potential oil and natural gas reservoirs and is one of the most promising areas in the country. Since the 1970s, Petrobras has been conducting exploratory activities, including the acquisition of 2D and 3D seismic data and well drilling operations. Thanks to modern seismic data processing software, it is now possible to reprocess legacy data acquired in previous decades to obtain new geophysical and geological information about the Barreirinhas basin. This study aims to reprocess the onshore seismic lines of the aforementioned basin using standard and advanced processing techniques. These include pre-stack data regularization based on the Common Reflection Surface (CRS) stack method. This work presents the preliminary results of the reprocessing of a seismic line. Using CRS-based processing has significantly improved the quality of the data, increasing the signal-to-noise ratio and enhancing the definition of reflectors throughout the migrated image.

Introduction

The Barreirinhas basin is located in the northern region of northeastern Brazil. It extends from the onshore to the offshore portion with boundaries defined by the Tutóia High to the east, the Santana Island Platform to the west and the Sobradinho Platform to the south, where it forms part of the Brazilian Equatorial Margin. It originated in an Aptian-age rifting region, associated with the separation of the South American and African continents. Therefore, its geological history is intrinsically linked to the tectonic evolution of the equatorial margin, whose rupture in this sector developed primarily grabenform structures, where the geophysical signatures and architectural fills are the subject of this study. These grabens and their corresponding horsts are bounded by a system of normal faults predominantly trending NW-SE and E-W. The rift-phase infill is characterized by continental deposits, such as fluvial and lacustrine sandstones, embedded in thick deltaic and lagoonal pelitic sequences. The basin has been the target of exploration by oil companies due to its well-defined petroleum systems with potential to generate and store hydrocarbons. The first exploration cycle of the onshore portion took place between the 1950s and 1970s, with the drilling of 71 wells and the acquisition of geophysical data. The second cycle, in the 1980s, included 31 wells and both onshore and offshore seismic acquisitions (Figure 1). Since the 2000s, a third exploratory cycle has been carried out, with the drilling of 3 wells in deep-water offshore portion, and 2D and 3D seismic surveys (ANP, 2021). Despite the challenges in characterizing reservoirs, especially due to the lack of information of source rocks and the origin of hydrocarbons, oil and gas exploration along the Equatorial Margin remains of great scientific interest. Ongoing studies aim to better understand the basin's formation and potential (Castro et al., 2022, 2024).

Reprocessing geophysical data aims to improve the quality of results from old data, using modern software and processing techniques. In seismic reflection exploration, processing vintage data using modern techniques is usually more cost-effective and feasible than acquiring new seismic data, as it allows more accurate interpretation of geological structures. This study aims to reprocess onshore seismic lines of the Barreirinhas basin to obtain more reliable imaging of geological structures. This will enable new seismic and geological interpretations, improving the identification of structures with potential for hydrocarbon storage. The study employs conventional processing techniques using commercial software, as well as a special processing technique based on pre-stack data interpolation and regularization using the CRS method (Garabito, 2021). The ultimate goal is to use the reprocessed lines for seismic interpretation in order to extract new geophysical and geological information and to contribute a better understanding of the basin. This abstract only presents the results of a single seismic line, but processing of all onshore seismic lines is in progress.

Figure 1: Location of the Barreirinhas basin and terrestrial seismic lines. Source: ANP (2021).

Methodology

This study presents the preliminary results of the reprocessing of a seismic line from the Barreirinhas basin (Figure 1). Seismic reprocessing was carried out using standard techniques of the ProMax/SeisSpace software (licensed by the PetroGeo Laboratory/DPET/UFRN) and proprietary software for special processing including pre-stack data reconstruction based on the CRS method and Kirchhoff pre-stack time migration (PSTM) from a floating datum. The standard processing workflow is as follows: 1) Geometry setup; 2) Polarity correction and noisy traces removal; 3) Spectral analysis and FK filtering for ground roll attenuation; 4) Spherical divergence correction; 5) Source and receiver amplitude compensation; 6) Surface-consistent deconvolution; 7) First-arrival picking, static correction calculation, and application to floating datum; 8) Velocity analysis; 9) Residual static correction; 10) Second velocity analysis; 11) Second residual static correction; 12) Pre-stack time migration; 13) Mute analysis and stacking of migrated gathers; 14) Post-stack filtering of the PSTM image. The special processing took as input the pre-stack data from step 11 and consisted of: 1) CRS attribute estimation using global optimization; 2) Pre-stack data interpolation and regularization using the CRS method; 3) Pre-stack time migration; 4) Mute analysis and stacking of migrated gathers; 5) Post-stack filtering of the CRS-PSTM image.

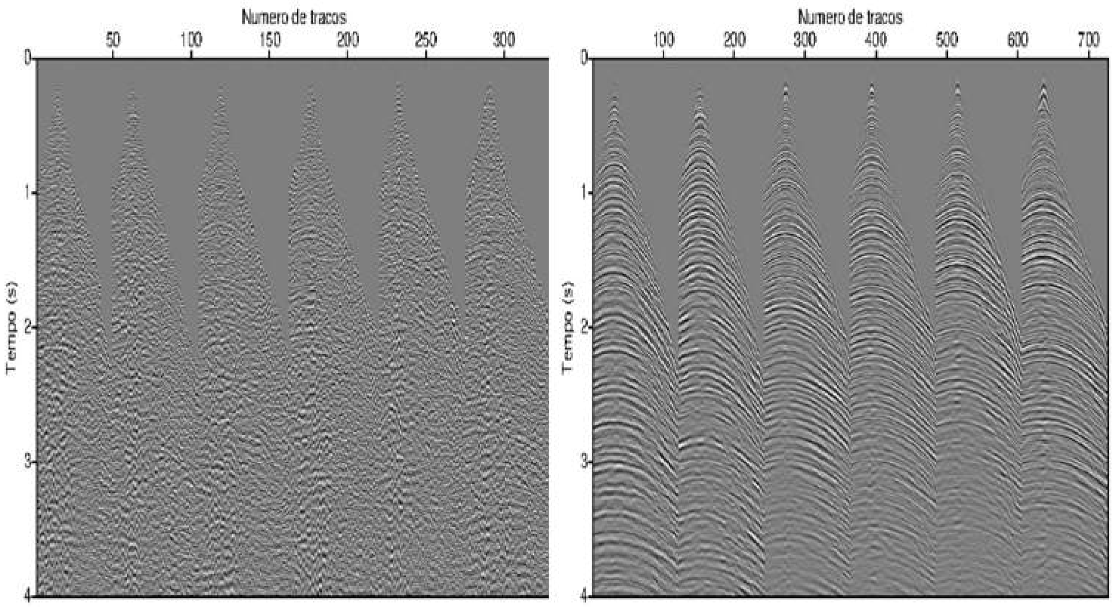

Figure 2: Common shot gathers extracted from the Barreirinhas basin seismic line: a) conventional processing and b) pre-conditioning with the CRS method.

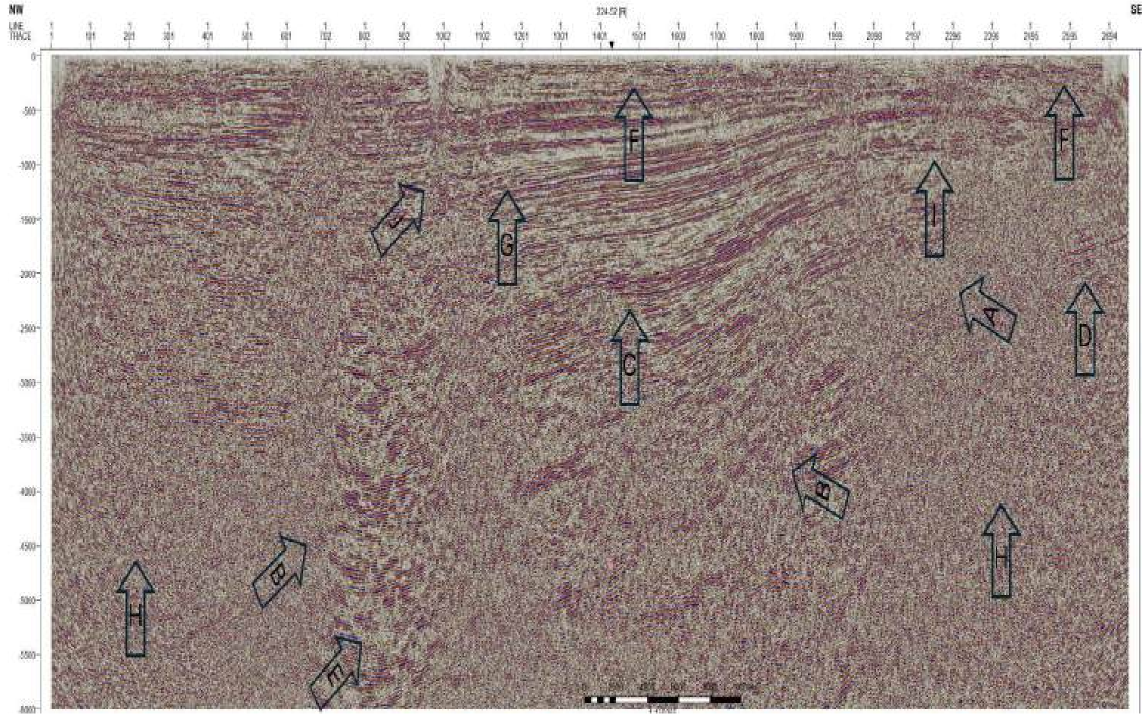

Figure 3: Conventional Processing: PSTM image from a seismic line in the Barreirinhas basin.

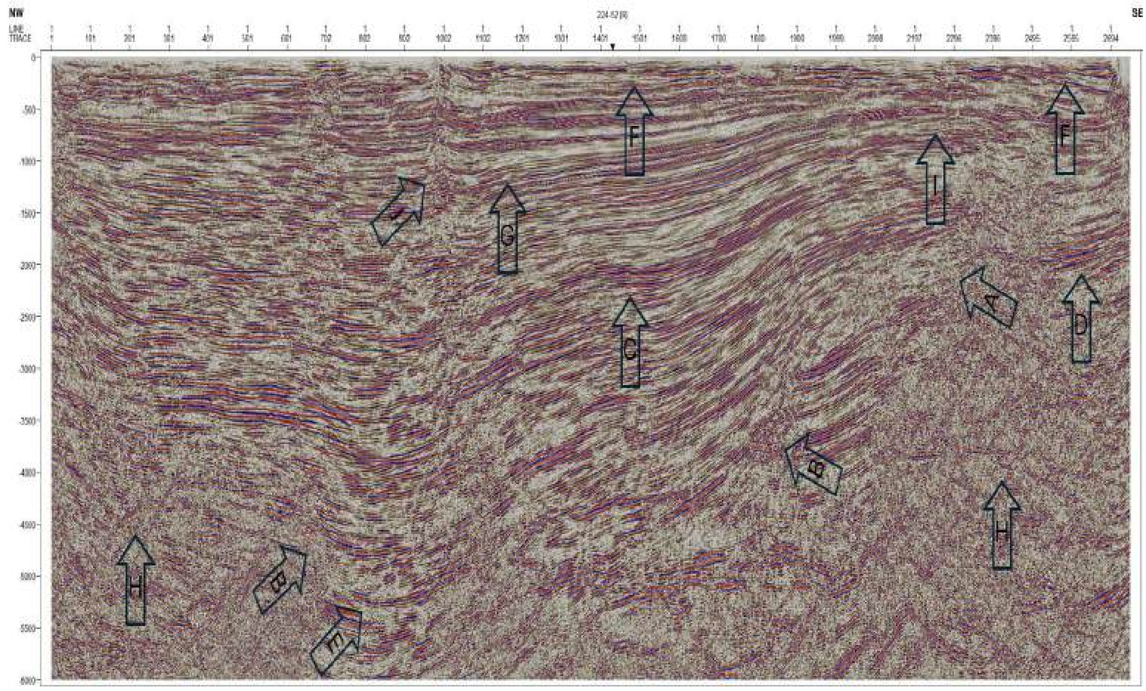

Figure 4: Special Processing: CRS-PSTM image from a seismic line in the Barreirinhas basin.

Results

This section presents the results of the processing and interpretative analysis of a seismic line from the Barreirinhas basin. Firstly, we present the pre-stack seismic data prepared for PSTM application. Figure 2a shows six Common shot gathers (CDP) sections from different locations along the line processed using the standard workflow. Figure 2b shows the same CDP sections interpolated and regularized using the CRS method. The standard-processed CDP sections reveal few weak-amplitude reflections that are mixed or blurred with strong noise. In contrast, the CRS-preconditioned CDPs show a significant improvement in quality, with a higher signal-to-noise ratio and clearly defined reflections throughout the sections. The difference in the number of traces I Figures 2a and 2b shows that the reconstruction or preconditioning of the data doubled the number of traces in the sections. The PSTM Kirchhoff migration, which is performed from the floating datum, was applied to the aforementioned pre-stack data. Figures 3 and 4 show the PSTM migration results from standard and CRS-based processing, respectively. Both images were generated using the same mute to the migrated gathers and the same post-stack filters.

There are clear and marked differences between the results. The CRS-PSTM image (Figure 4) is significantly superior to the standard PSTM (Figure 3), as the following observations highlight: 1) The continuity of the reflectors has improved significantly, showing the truncations against the fault (A) as well as outlining the plane of the main faults, especially those associated with the graben-form system (B). Similarly, the events linked to the development of internal discordances and/or terminations were also better marked (C). 2) The CRS-PSTM image displays a slightly lower frequency content compared to the standard PSTM, along with the presence of X-shaped noise in certain areas. On the other hand, there is a clear recovery of coherent events with continuous amplitudes, possibly linked to the existence of sedimentary packages at deeper intervals (D). This enables confident inference of deeper graben depocenters (E), supported by continuous reflectors and their restriction to the fault plane. Near-surface reflectors are also better defined, highlighting structural discontinuities and tabular packages (F). 3) Packages of seismofacies show good lateral correlation, which indicates wedge-shaped stratification, a typical feature of rift environments (G). Basement-related seismofacies are very well characterized at the places related to the high blocks of edge faults (H). 4) The structural inversions of the dips of the layers are clearly marked and the high blocks of the edge faults are easily identifiable. These soft folds, known as forced folds, occur on the positive levels of the faults (I), making them excellent hydrocarbon traps. 5) The CRS-PSTM image also highlights another interesting feature, namely the possibility of occurrence DHI (direct hydrocarbon indicators), which resemble gas escape zones (J). These lateral reflector dissimilarities are interpreted as features indicating zones of gas escape, which is consistent with the well-known gas-prone compartments of the basin.

Conclusions

The preliminary results presented in this abstract demonstrate that reprocessing vintage seismic data using the CRS-PSTM workflow provides better quality results, as it attenuates noise and strongly emphasizes coherent events such as seismic reflections. The results of reprocessing of all onshore seismic data using the CRS-PSTM method will contribute to better geological and geophysical knowledge of the Barreirinhas Basin. This will allow for better structural and stratigraphic seismic interpretation, and consequently better mapping and characterization of structures suitable for hydrocarbon storage.

Acknowledgments

We would like to thank Petrobras for sponsoring the MECO Project, FINEP for supporting a project under the agreement 01.23.0522.00 FINEP/UFRN/FUNPEC, and CNPq for supporting project 306393/2022-0.

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