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Common Reflection Point Regularization: Application in a 2D land dataset from Potiguar basin

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Abstract

Seismic datasets often exhibit inherent irregularities, such as variations in acquisition geometry, failed receivers, and changes in noise levels between shots. These irregularities introduce significant challenges in seismic processing efforts and may compromise image quality. To address this challenge, various regularization techniques have been developed to refine these datasets by eliminating noise and regularizing grid data to enhance seismic imaging results. In the context of this study, we employed Common Reflection Point (CRP) Regularization to generate a regular grid and also improve the signal-to-noise ratio of a 2D seismic dataset acquired from the Potiguar basin. The application of the CRP Regularization yielded good results, being able to increase fold coverage while preserving the underlying geological structures.

Introduction

Seismic datasets from 2D land surveys often suffer from inherent limitations, including sparse coverage, compromised signal-to-noise ratios (S/N), and irregular offset distributions. These issues are frequently caused by equipment malfunctions and natural or operational constraints. The accuracy and reliability of seismic processing methods rely heavily on the quality of input data, emphasizing the need for effective preprocessing techniques to mitigate these problems. In response, various prestack data interpolation, extrapolation and regularization methodologies have been developed, drawing from distinct approaches such as Common-Reflection-Surface (CRS) stacking (Souza et al., 2025; Zhang et al., 2001), Multifocus stacking (Landa et al., 1999), and Offset-Continuation-Trajectory (OCT) stacking (Coimbra et al., 2016).

This study applies a Common-Reflection Point (CRP) stacking technique as a regularization method to an onshore Brazilian dataset from the Potiguar Basin, which exhibits low fold, irregular grid configurations, and poor S/N ratios. Recognizing that seismic line irregularities can introduce artifacts into migrated results, we employed standard seismic processing procedures in conjunction with CRP stacking in the common-offset (CO) domain to rectify offset inconsistencies and enhance spatial density. The regularized dataset was subsequently used as input for prestack time migration (PSTM), allowing for a comprehensive comparison of processing outcomes between the original and reformatted datasets.

Method

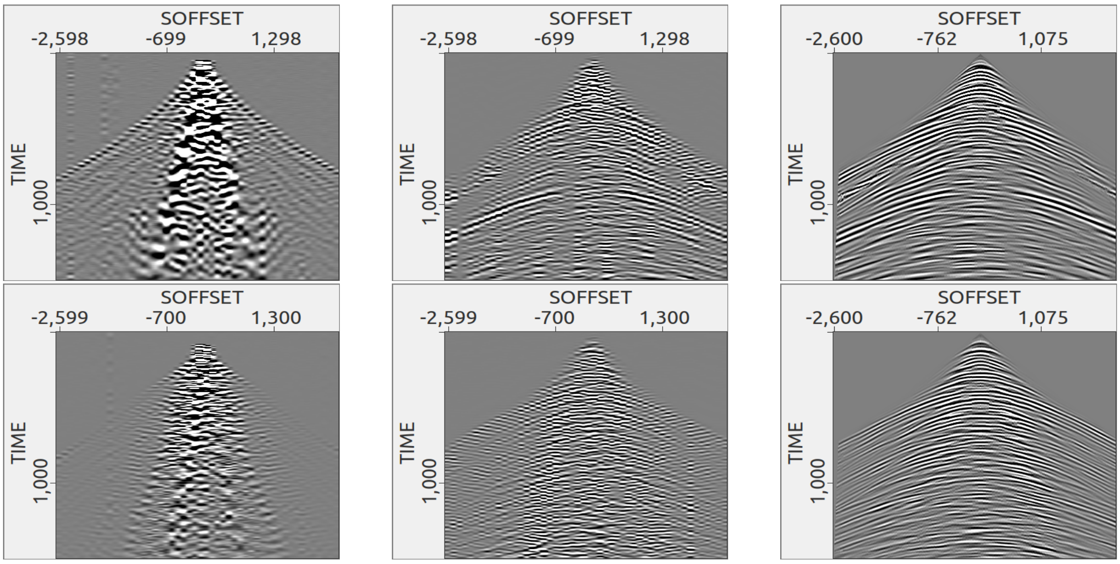
The CRP Regularization (Mundim et al., 2024) is based on OCT stacking, which computes CRP trajectories that approximate the position of reflection events in the data as a function of source-receiver offset and midpoint position. This process requires only two kinematic parameters for 2D acquisition geometries: the local slope in midpoint direction and a stacking velocity. These parameters are estimated by a global search algorithm (Ribeiro et al., 2023) at each sample of the desired output acquisition geometry. Subsequently, the data can be stacked along a traveltime surface that approximates the best-fitting CRP event crossing that sample.

Since this process considers amplitudes related to the same reflection point, it has the potential to enhance data stacking avoiding the mixing of amplitudes from different reflection points along the same event. Parameter estimation and the stacking can be performed at any acquisition geometry, whether the original or a regularized one. This flexibility makes the method suitable for dataset enhancement while preserving the source-receiver geometries, or data set regularization.

Results

A conventional seismic processing workflow was applied to the 2D land seismic line 0230-774 from the onshore portion of the Potiguar basin using Shearwater Reveal software (Shearwater GeoServices Software, 2024). The processing sequence began with standard pre-processing techniques to prepare the data for further analysis. As depicted in Figure 1 (a), the original CMP gather, with a nominal fold of 50 traces, presented characteristics typical of land seismic acquisitions, including strong dispersive ground roll and ambient noise.

Following this initial pre-processing, the seismic line was edited to remove faulty traces associated with defective geophones and attenuate the ground roll, as shown in Figure 1 (b). This step enhanced the quality of the gathers by minimizing artifacts and improving signal-to-noise ratios. This pre-processed dataset was then used as input for the CRP Regularization, which resulted in a regularized CMP gather, as shown in Figure 1 (c). The regularized gather, comprising 401 traces (fold), shows effective ambient noise attenuation and exhibits well-defined, continuous events that are more suitable for migration and can also improve further velocity analysis procedures.



(a) Original. (b) Pre-processed. (c) Regularized.

Figure 1: CMP gathers 146 (top) and 314 (bottom) of seismic line 0230-774 comparing original, pre-processed, and regularized data.

The CRP Regularization was further evaluated by comparing Kirchhoff PSTM results obtained from both preprocessed and regularized seismic lines (Figures 2 and 3). Notably, the events in the regularized dataset exhibited improved S/N and continuity while maintaining their original positions and preserving the distinct features and details of the original line. Artifacts related to geometry irregularities were also reduced, especially in shallow regions.

Conclusions

Traditional land seismic lines often suffer from inherent noise and spatial irregularities, stemming from various natural and operational constraints. However, incorporating CRP regularization into the data preprocessing workflow significantly improved the quality and resolution of the seismic line, especially in the prestack domain. CRP stacking not only created a regular CMP gather but also substantially increased fold density and enhanced S/N, allowing for more detailed imaging. Furthermore, the technique improved the overall quality of the reflectors, maintaining their geological integrity with minimal to no artificial distortions. Notably, migration artifacts were significantly reduced, resulting in cleaner seismic images. These findings illustrate the potential of CRP regularization as a valuable tool for 2D seismic data regularization, offering a promising approach for overcoming common challenges associated with traditional land seismic lines. By addressing spatial irregularities and noise-related issues, CRP stacking can contribute to improved image quality, enhanced interpretability, and refined stacking and migration velocities.

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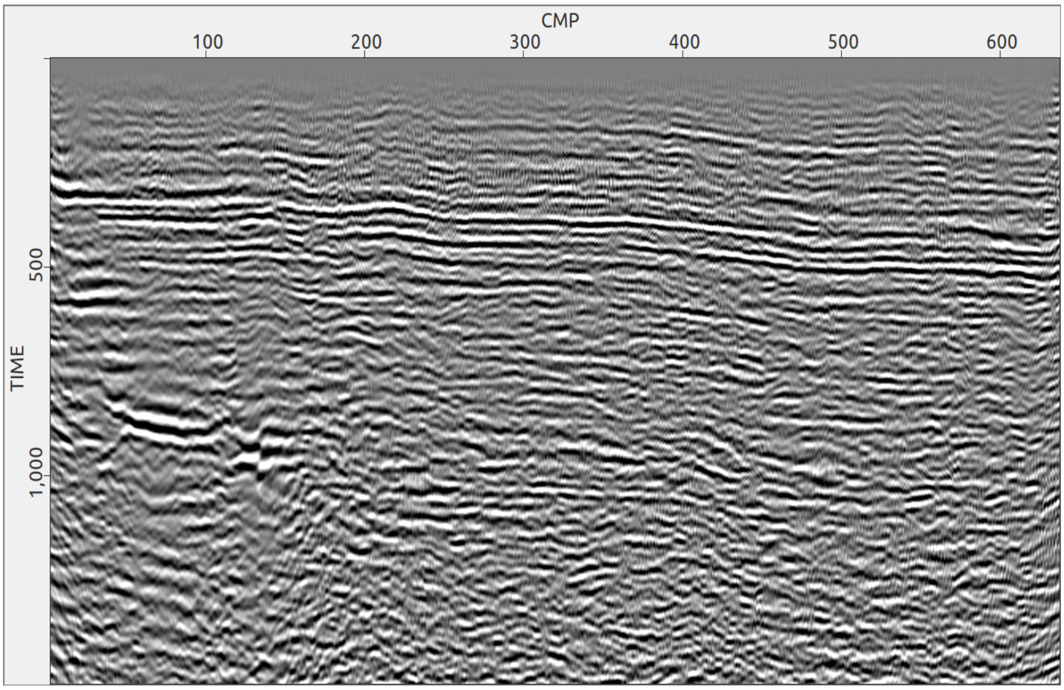

Figure 2: Kirchhoff PSTM obtained with the pre-processed data.

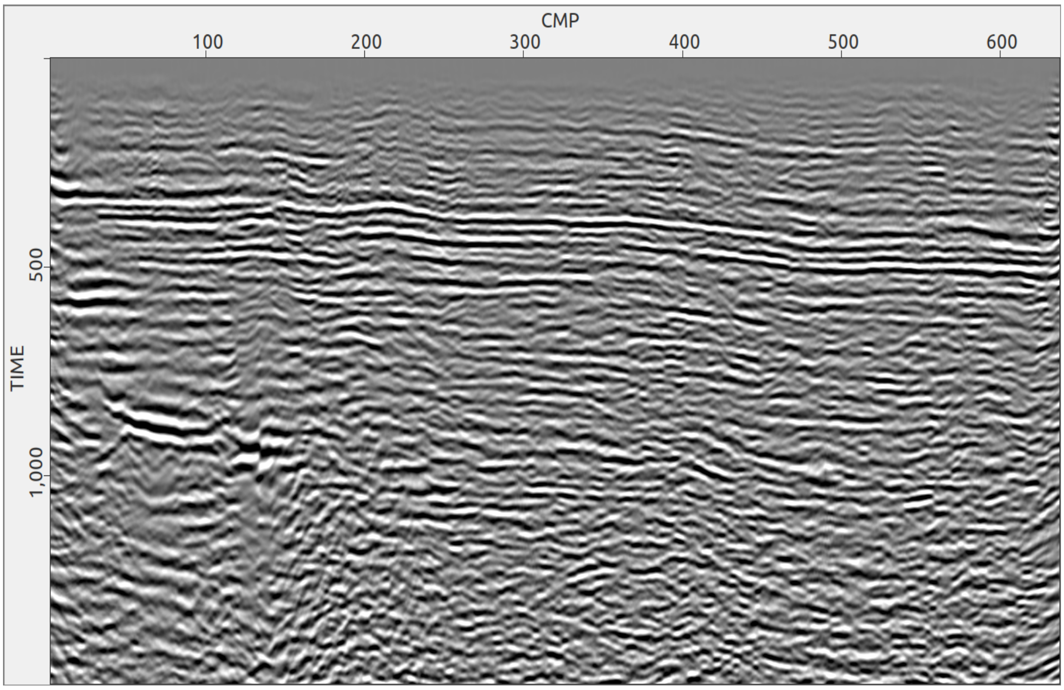

Figure 3: Kirchhoff PSTM obtained with the regularized data.