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Enhancing Interpretation Through Gather Conditioning in the Volve Field

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Abstract Summary

We present a comprehensive gather conditioning workflow applied to a subset of the Volve dataset to improve seismic interpretability. Starting with migrated seismic gathers, we applied trace muting to suppress far-offset noise, used Radon transform techniques to attenuate both random and coherent noise, corrected long-offset residual normal moveout to ensure phase alignment, and applied statistical deconvolution to enhance frequency bandwidth. Each stage was followed by rigorous quality control, including comparisons of raw and conditioned gathers, analysis of removed noise, AVO gradient validation, and spectral analysis. Horizon interpretation was then performed on stacked volumes derived from both raw and conditioned gathers. The results clearly demonstrate that the conditioned data produced more continuous, noise-reduced, and spectrally rich events, enabling significantly more reliable and accurate seismic horizon interpretation.

Introduction

Seismic data conditioning is a critical step in ensuring reliable inversion results and accurate seismic reservoir characterization, as shown in Oliveira et al. (2018). Comparison of inversion results from raw data and from seismic conditioned data consistently show improved resolution, signal fidelity, and geologic interpretability. For example, Zhang et al. (2015) compared the improvements of gather conditioning with raw data for prestack inversion and Meneguim et al. (2017) showed the benefits of poststack seismic data conditioning on impedance inversion.

Horizon interpretation is a fundamental component of reservoir characterization. It enables geoscientists to accurately map key stratigraphic and structural surfaces, which are essential for identifying traps, compartments, and reservoir boundaries. In addition to supporting structural understanding, horizon interpretation also underpins quantitative interpretation, serving as the foundation for extracting meaningful insights from subsurface data. Poor or inaccurate horizon picking can lead to significant setbacks, including time-consuming rework, mischaracterization of reservoir architecture, and ultimately, missed business opportunities. Typically, local automated horizon-mapping methods rely on seed-based auto-tracking to extract horizons by correlating the local amplitude between adjacent traces (Figueiredo et al., 2014). More advanced methods, including deep learning methods, have been proposed to address these limitations (Zeng et al., 1998; Figueiredo et al., 2014; Tschannen et al., 2020).

In this work, we introduce a robust gather conditioning workflow applied to a subset of the Volve dataset (Equinor, 2018), aimed at improving horizon interpretation accuracy through enhanced signal quality and frequency content. Our approach attenuates both random and coherent noise, corrects long-offset residual moveout, and boosts vertical resolution via statistical deconvolution. The resulting conditioned gathers exhibit flatter, more continuous events, which are preserved through stacking and directly improve the consistency and reliability of automatic horizon interpretation.

Method

We applied the seismic data workflow to increase the signal-to-noise ratio, quality-controlled each step, and then performed automatic horizon interpretation to compare the effect on raw and conditioned data.

The main steps for preconditioning the seismic data are: 1) Super Gather: creating offset gathers sorted by CDP binning the input seismic traces in a series of regular offsets, 2) Trace Muting: reducing noise while preserving critical signal amplitudes in the far-offset traces, 3) Radon De-noise and De-multiple: utilizing Radon-based techniques to remove random noise and multiple reflections, 4) Long Offset Residual Normal Moveout Correction: addressing residual normal moveout observed in long-offset seismic traces incorporating non-hyperbolic corrections using higher-order approximations, and 5) Statistical Deconvolution: deconvolving a seismic volume using the autocorrelation of the trace to derive its operator to increase the vertical resolution of the seismic data.

The effectiveness of the preconditioning workflow was validated through quality control (QC) measures, including: 1) Removed noise: comparisons between input gather, conditioned gather and removed noise, 2) AVO Gradient Analysis: analysis of the AVO curves at the top of interest, and 3) Spectral Analysis: amplitude spectra comparisons between raw and conditioned gather data, and between raw and stacked data.

Results

We applied our gather conditioning workflow to a subset of the Volve dataset (Equinor, 2018). The Volve field is located in the central part of the North Sea. It is part of a geologically complex region with faulted and tilted structures (Jackson et al., 2010). These features can indeed introduce discontinuities and complexities in seismic interpretation, particularly around faults. The main reservoir of interest is the Hugin Formation (Pelemo-Daniels and Stewart, 2024).

Figures 1a-c show the raw gather, the conditioned gather and the removed noise, respectively. As a QC, the inset in Figure 1c shows the amplitude spectrum for the raw (in brown) and the conditioned gather (in blue). The signal to noise ratio was increased, the frequency content was enhanced, the noise was attenuated, the events are flatter and preserved.

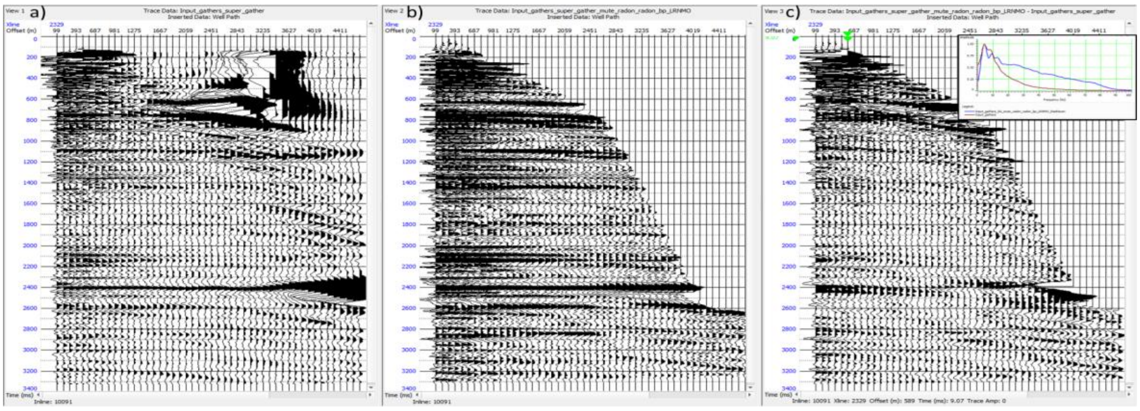

Figure 1: a) Raw gather, b) conditioned gather, and c) removed noise. The inset in panel c) displays the amplitude spectra, with the raw (in brown) and the conditioned gather (in blue).

Figures 2a and 2b show the raw and conditioned gathers, respectively. The formation of interest is picked in both gathers, red in the raw gather and blue in the conditioned gather. Figure 2c shows the AVO analysis for the picked events in Figures 2a and 2b. The points are the amplitudes at the event position and the continuous curves show a fit using the two term Aki-Richards approximation. This figure shows the preservation of amplitude variation with offset after conditioning.

Figures 3a and 3b show the stacks from the raw and conditioned data, respectively. Notice the increase in the frequency content and the definition of events after noise attenuation. Figures 3c and 3d are the zooms of Figures 3a and 3b, respectively. Two horizons were automatically interpreted at these data, the arrows point to the position of the initial pick. Figure 3c shows the horizon in red and Figure 3d shows the horizon in blue. Notice that the automatic interpretation in Figure 3c fails due to low signal to noise ratio in the raw data. Whereas the blue horizon, interpreted in the conditioned data, in Figure 3d shows consistency. The inset in Figure 3c shows the amplitude spectrum of the raw stacked data, in brown, and the conditioned stacked data, in blue.

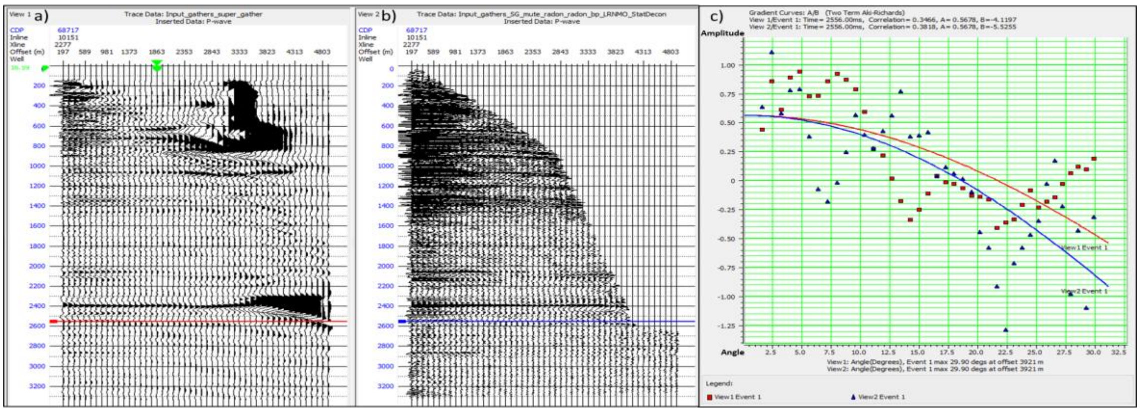

Figure 2: Raw and conditioned gathers with corresponding AVO analysis. a) Raw gather data, b) conditioned gather data, and c) AVO analysis of the picked events. The colors of the events picked on the gathers correspond to the colors used in the AVO plot.

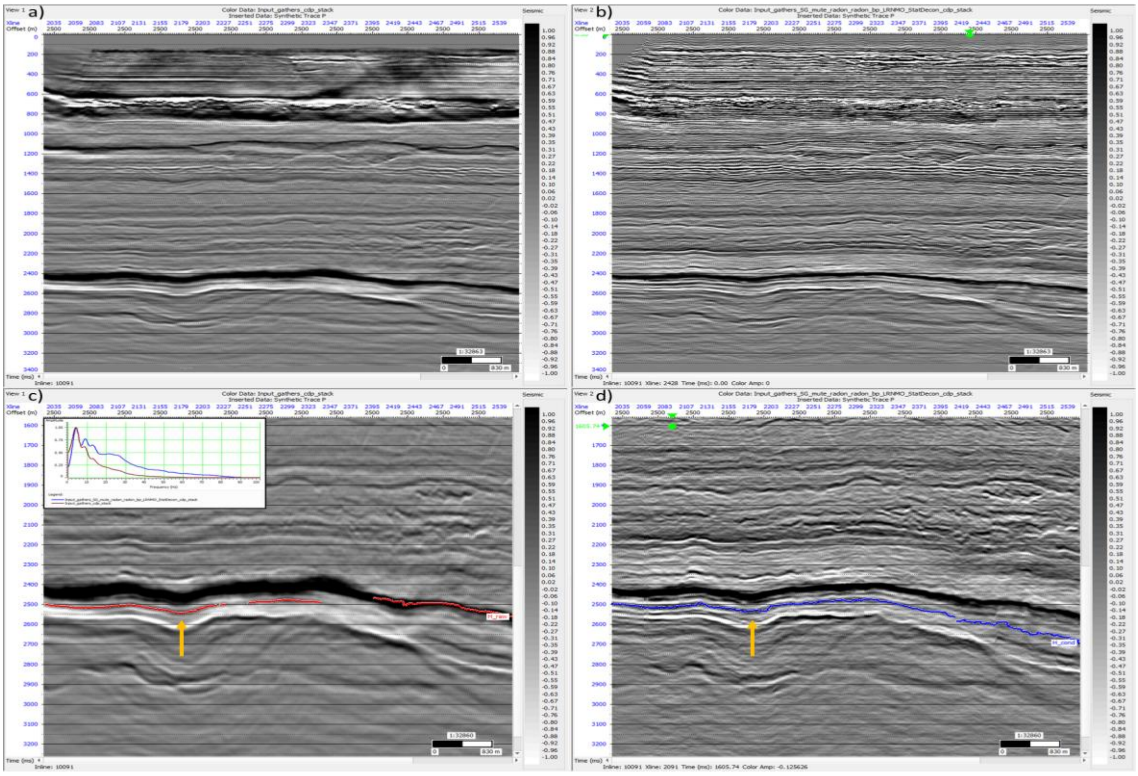

Figure 3: Stacks and automatically interpreted horizons. a) Raw data stack and b) conditioned data stack. c) Zoom at the raw data stack with automatically interpreted horizon in red, the inset shows the amplitude spectra of the raw stacked data, in brown, and the conditioned stacked data, in blue. d) Zoom at the conditioned data stack with automatically interpreted horizon in blue. The arrows point to the position of the initial pick.

Conclusions

In this study, we applied a gather conditioning workflow to a subset of the Volve dataset, resulting in significant improvements in data quality. The process effectively enhanced the signal-to-noise ratio by attenuating both random and coherent noise, preserved AVO responses, and increased frequency content in both gathers and stacked sections.

Key benefits of the workflow include: 1) enhanced seismic data quality, supporting more reliable interpretation and inversion workflows, 2) preservation of amplitude fidelity and event continuity, enabling accurate AVO and spectral analysis and 3) improved automatic horizon interpretation, reducing manual effort and boosting geological modeling efficiency.

Quality control at each step confirmed that seismic events were not only preserved but also enhanced, leading to clearer and more continuous horizons, enabling better delineation of stratigraphic and structural features. This contrasts sharply with the fragmented and ambiguous events seen in the raw data, which often led to incorrect horizon picks. This study underscores the importance of gather conditioning as a foundational step in seismic interpretation workflows, particularly when dealing with legacy or lower-quality datasets. Enhanced horizon interpretation through data conditioning not only improves geophysical analysis but also contributes to more efficient exploration workflows and robust subsurface models.

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