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Enhancing Seismic Interpretations with Seismic Super Resolution Method: A Novel Approach for Improved Subsurface Characterization

C. Li, B. Macy, J. Bowling, B. Roy, ConocoPhillips

Objective/Scope: The aim of this abstract is to introduce and illustrate the Seismic Super Resolution (SSR) method, which enhances the resolution of seismic data crucial for geological interpretations. This proprietary method, developed internally at ConocoPhillips, targets delineating thin reservoirs and improving resolution under complex structural settings.

Methods, Procedures, Process: Our approach integrates techniques from computer vision and geophysics to address the inherent limitations of seismic data, which is typically band-limited due to the anelastic effects of wave propagation. The SSR method applies principles of single-image super resolution from the field of image processing, specifically using total variation regularization. This regularization technique is well-suited to seismic data as it promotes the local homogeneity typical of geological layers. The method involves the simultaneous regularization of reflectivity and acoustic impedance models, employing sparse inversion and convex optimization techniques. We deliberately exclude well data in early inversion stages to prevent introducing bias.

Results, Observations, Conclusions: We use a synthetic example of a wedge model to demonstrate the robustness of the SSR method in handling noisy data compared to spiking deconvolution. The synthetic data was generated using a wedge model with Gaussian reflection coefficients and a 30 Hz Ricker wavelet, as shown in Figure 1a and 1b. To evaluate robustness of the method, 5% Gaussian noise was added to the synthetic seismic data (Figure 1c). The spiking deconvolution result (Figure 1d) shows an over-amplification of high-frequency content and noise, reducing its interpretability of wedge thickness. In contrast, the SSR result (Figure 1e) enhances resolution without over boosting the embedded noise. This is further validated in Figure 2, where the amplitude spectra reveal that spiking deconvolution amplifies both high-frequency content and noise, while the SSR method maintains a more noise-resistant spectrum.

Since its initial implementation in 2021, the SSR method has significantly contributed to exploration and field development across ConocoPhillips' assets in regions such as Eagle Ford,

Permian, Alaska, China Bohai, Norway, and Libya. It has shown potential in various applications, such as enhancing well planning, reducing drilling uncertainties, and improving reservoir delineation. The case studies presented involve applications in both conventional and unconventional fields, highlighting substantial improvements in seismic data interpretation and operational decisions. These results indicate not only the efficacy of SSR in resolving detailed subsurface features but also its impact on optimizing field developments and reducing uncertainties.

Novel/Additive Information: This abstract contributes new insights to the field of seismic imaging/inversion by adapting image super resolution techniques to seismic data, a novel approach that enhances data interpretation capabilities. The SSR method offers a significant advancement in the resolution of seismic images, thereby improving the ability to understand and exploit complex geological formations.

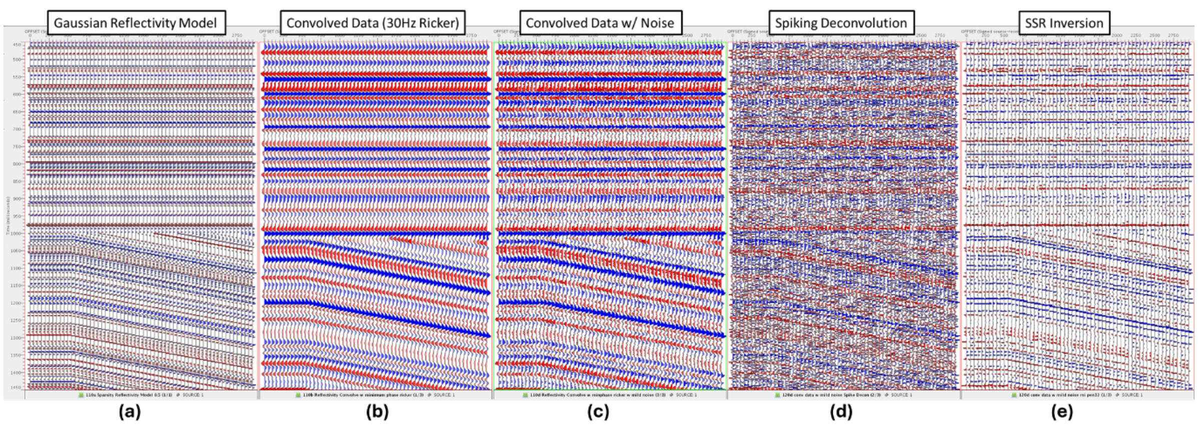

Figure 1: A synthetic example demonstrating the robustness of the SSR method to noisy data. (a) Synthetic wedge model with Gaussian reflection coefficients. (b) Synthetic seismic data generated using the wedge model and a 30 Hz Ricker wavelet. (c) Synthetic seismic data with 5% Gaussian noise added. (d) Spiking deconvolutions result derived from the noisy data in (c). (e) SSR result obtained from the noisy data in (c).

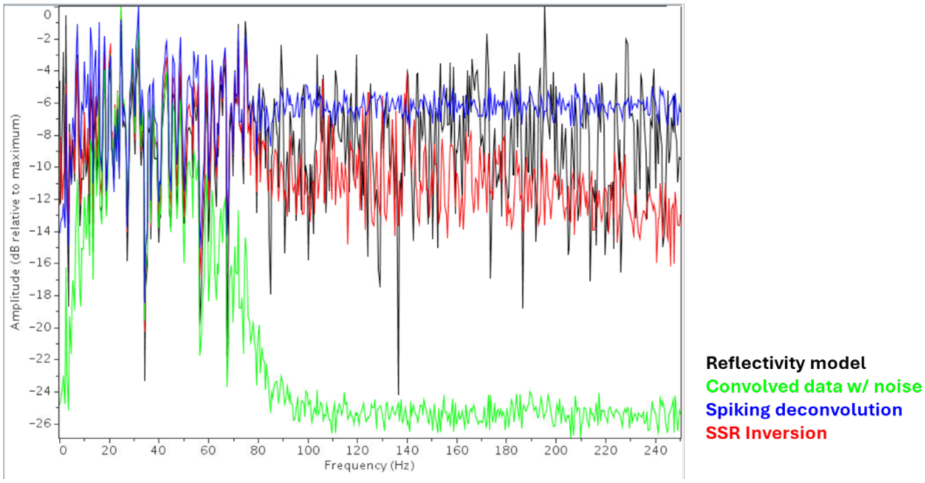

Figure 2: Comparison of amplitude spectra from spiking deconvolution and SSR inversion methods.