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Frequency enhancement applied to 3D seismic in the Permian Basin

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Summary

This presentation demonstrates the effectiveness of a novel bandwidth extension approach applied to a Permian Basin 3D seismic dataset, delivering higher-resolution imaging and more geologically consistent inversion results. The method employs the Multiscale Fourier Transform for time–frequency analysis, enabling the capture of both local and global amplitude relationships without the need for wavelet extraction, well control, or initial models, making it well suited for large-scale seismic and depth-migrated datasets. By improving data quality, the approach facilitates more accurate landing zone selection and lateral well planning, while also rejuvenating legacy and structurally complex datasets for detailed interpretation and well design. Overall, this method helps reduce drilling risk and enhance production performance.

Theory / Method

Key benefits of this method include the generation of band-limited impedance that is free from uncertainties associated with wavelet estimation, as well as reduced inversion artifacts caused by wavelet sidelobes that commonly affect conventional approaches. Uncertainty in time–depth conversion is also minimized, since the inversion can be performed directly in the depth domain. The results show improved vertical resolution relative to traditional band-limited inversion techniques. This machine-learning-based reflectivity inversion further enables the extraction of an implied 3D wavelet field, which can be leveraged for phase correction, Q estimation, and applications in full-waveform inversion (FWI) without contamination from the reflectivity spectrum.

Results, Observations, Conclusions

This methodology was applied to the West Kermit onshore PSDM dataset in the Permian Basin, USA, an area known for complex near-surface conditions, high noise levels, and limited high-frequency signal. Despite optimized acquisition design and advanced seismic processing, the legacy dataset remained bandwidth constrained and lacked adequate resolution. Application of the proposed technology extended the spectral content from approximately 40 to more than 60 wavenumbers, revealing significantly enhanced stratigraphic and structural detail that was previously unresolved. Subsequent band-limited impedance (BLI) inversion produced sharper formation boundaries and improved definition of subtle geologic features, supporting more

accurate interpretation and better-informed well placement decisions. In Figure 1, we are showing an inline extracted from the conditioned seismic data. Figure 2 demonstrates the strength of the bandwidth extension method by displaying the final results of the same inline.

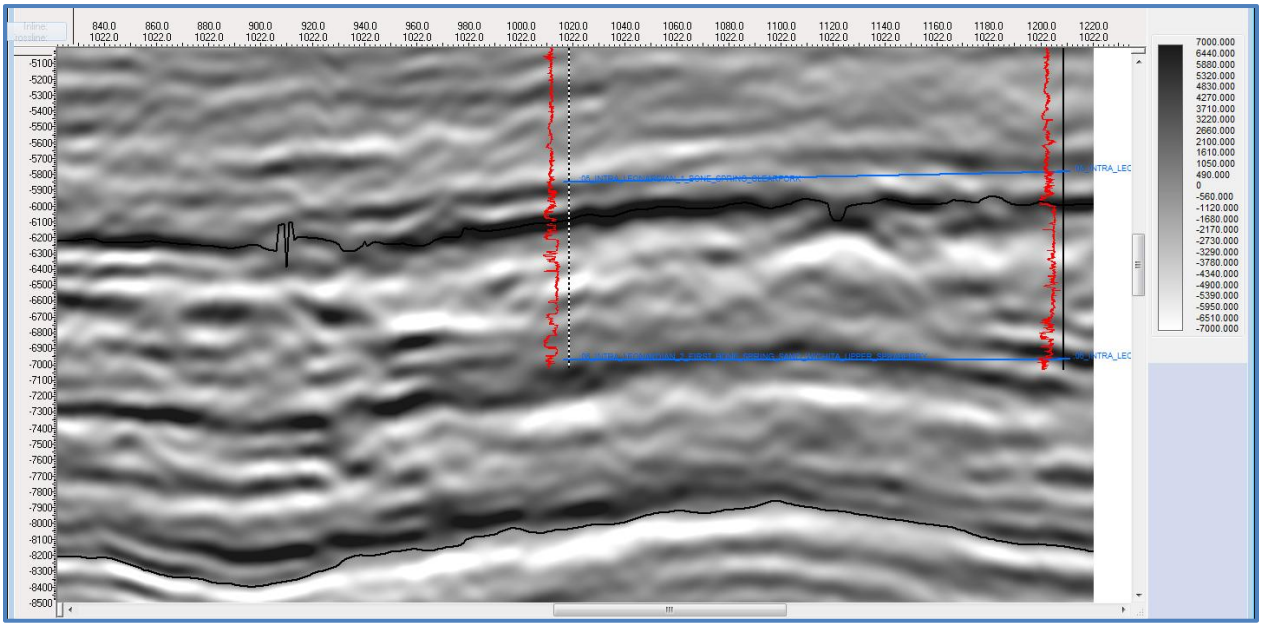


Figure 1. Input seismic data

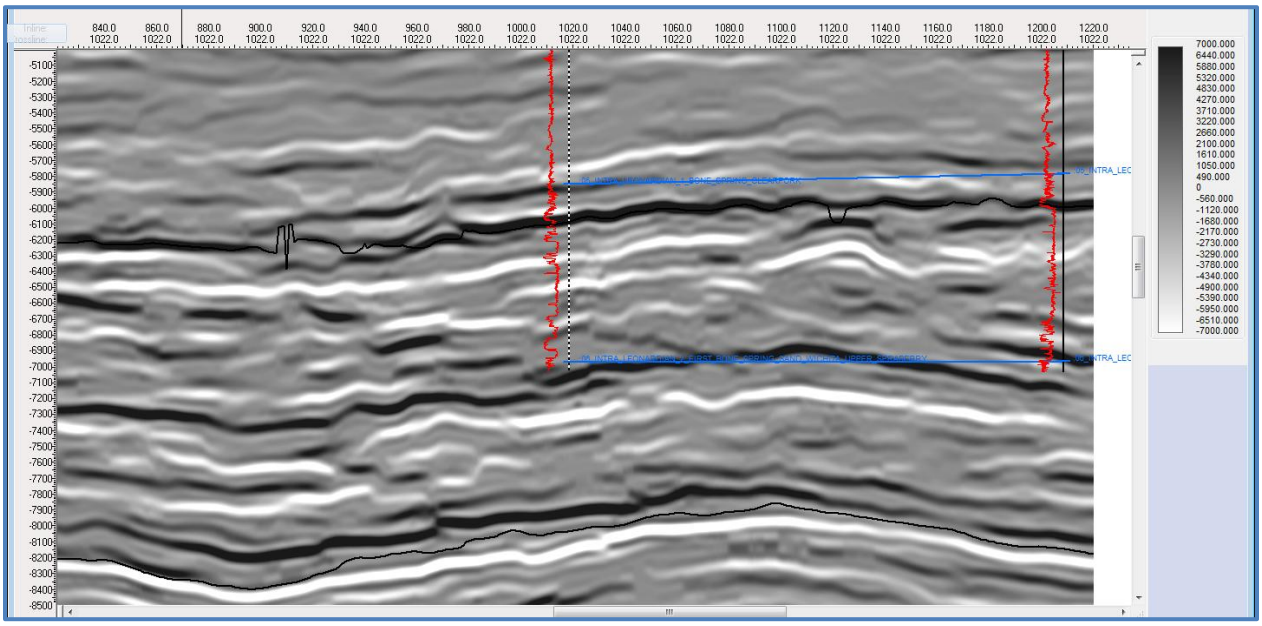


Figure 2: DeepInvert results

Novel

The frequency enhancement technique does not require a wavelet for the inversion process. Well information and such isn't being used during the processing. The results are amplitude preserving and phase stabilized and can be used for further attribute studies such as AVO, rock property conversion and pore-pressure prediction to name a few.

Acknowledgements

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References

Rauch, M., Barbato, U., Castagna, J., Fick, A. Adding value and breathing new life into difficult onshore seismic through a novel bandwidth extension approach. First Break, Volume 43, July 2025