A Transferable Seismic-Attribute Workflow to Detect Subtle Faults in CO_2 Storage Settings

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INTRODUCTION

The Taranaki Basin has undergone multiple tectonic phases that produced a structurally complex subsurface with subtle folding, weakly expressed faults, and reactivated lineaments.

These small-scale structures are difficult to resolve in conventional seismic data but are critical in the context of CO_2 sequestration, where minor faults can influence reservoir integrity, compartmentalization, and potential leakage risk. This study applies seismic attribute analysis to a 3D seismic dataset from the Taranaki Basin to enhance the visibility of subtle structural features and improve structural characterization for CO_2 storage and subsurface risk assessment.

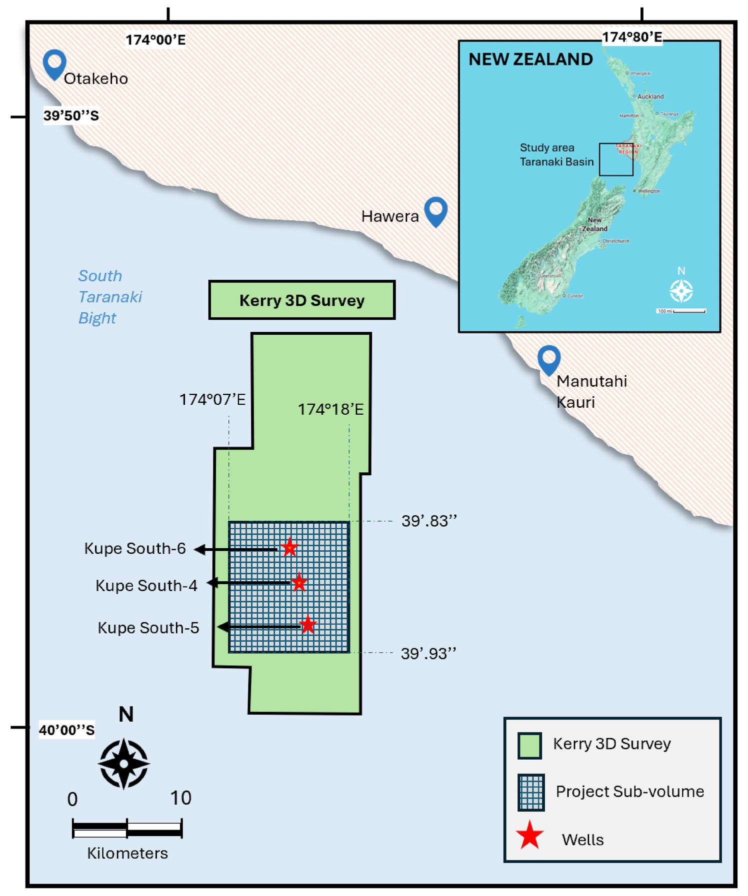


Figure 1: Location of the Taranaki Basin and the Kerry 3D seismic survey area. Modified from Bierbrauer & Leitner (2011)

FAULTS AND CO_2 STORAGE

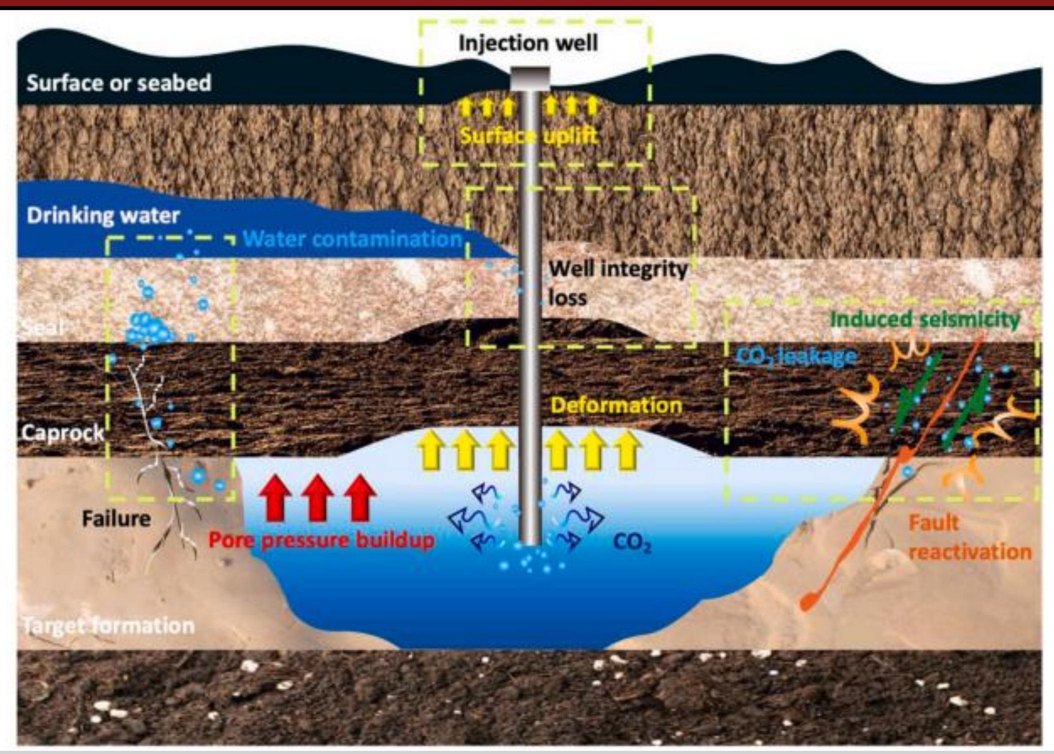


Figure 2: Geomechanical risks during CO_2 sequestration: stress changes, fault reactivation (Song, 2023)

METHODOLOGY

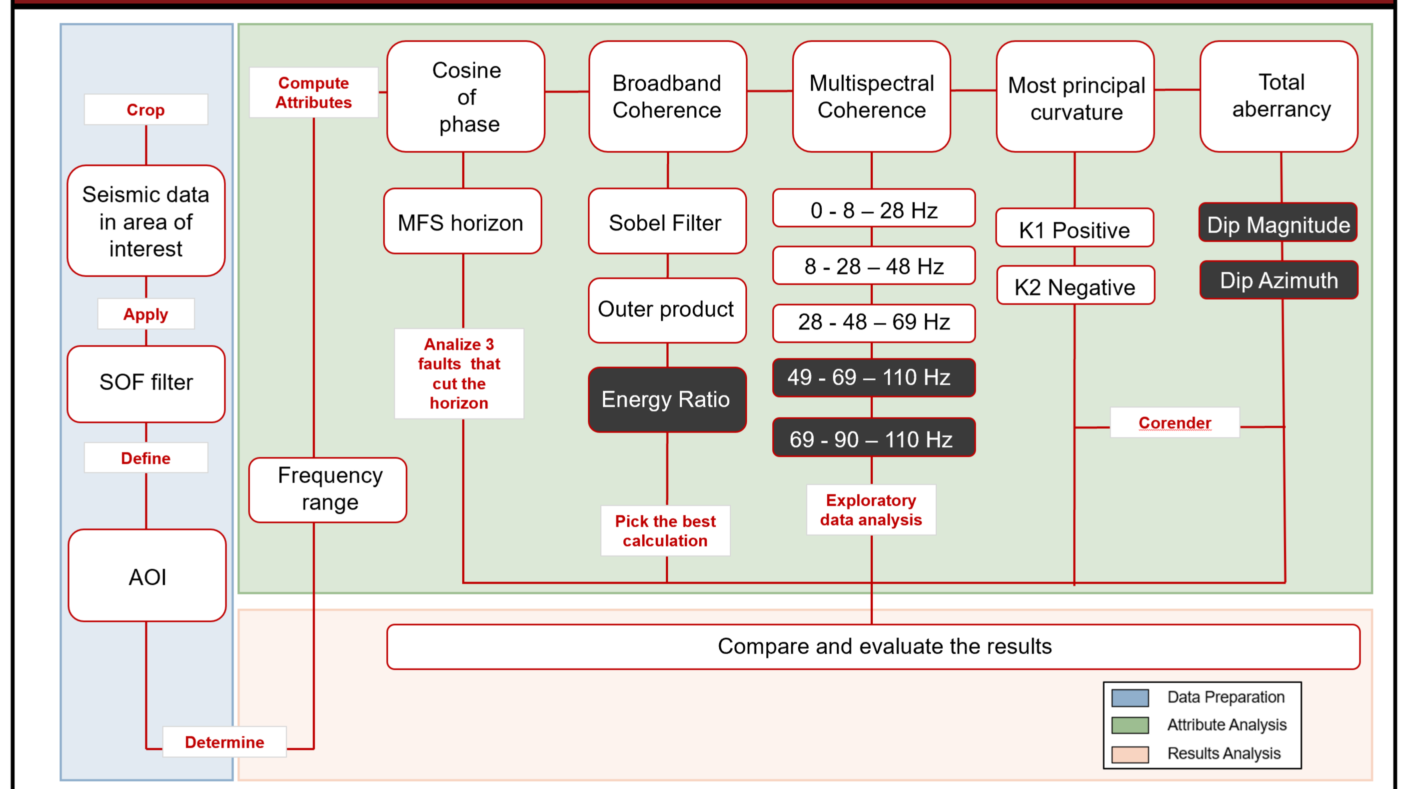


Figure 3: Detailed methodology for my project. Modified (Salazar & Bedle 2024).

DISCUSSION

Amplitude data alone can be improved by attribute-based analysis

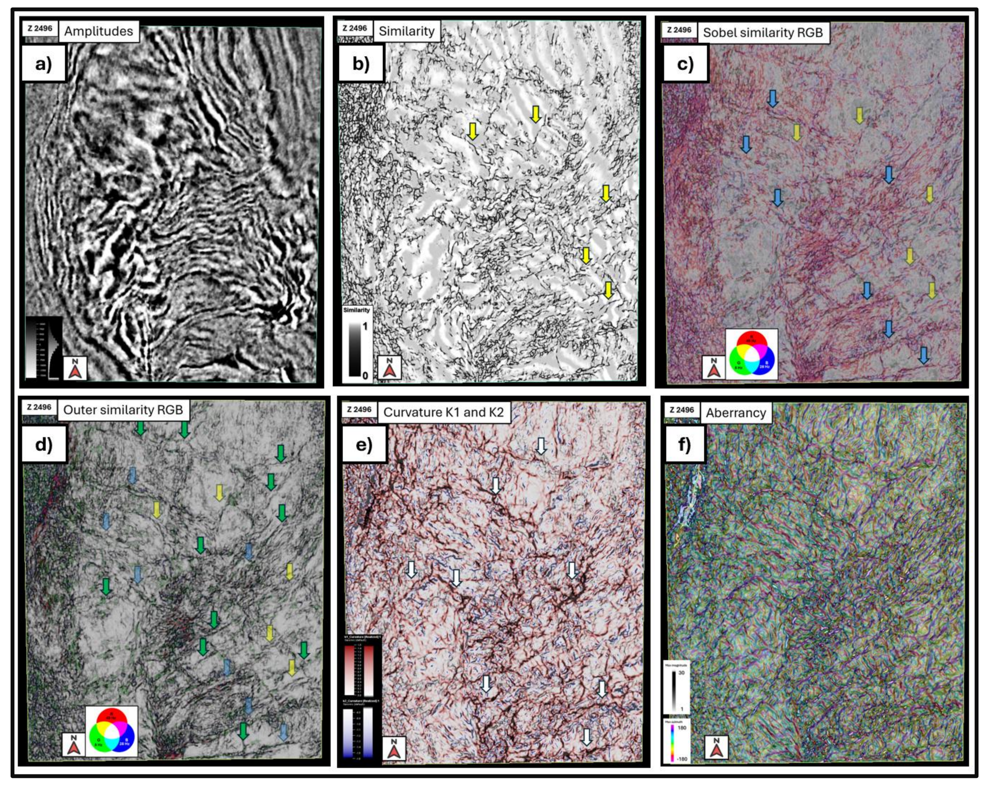


Figure 4. (a) Amplitude with limited fault expression.(b) Similarity showing weak lineaments.(c) Sobel similarity RGB highlighting improved continuity.(d) Outer similarity RGB revealing dense fault-related lineaments.(e) Curvature co-render showing deformation with high noise.(f) Aberrancy co-render indicating potential fault locations.

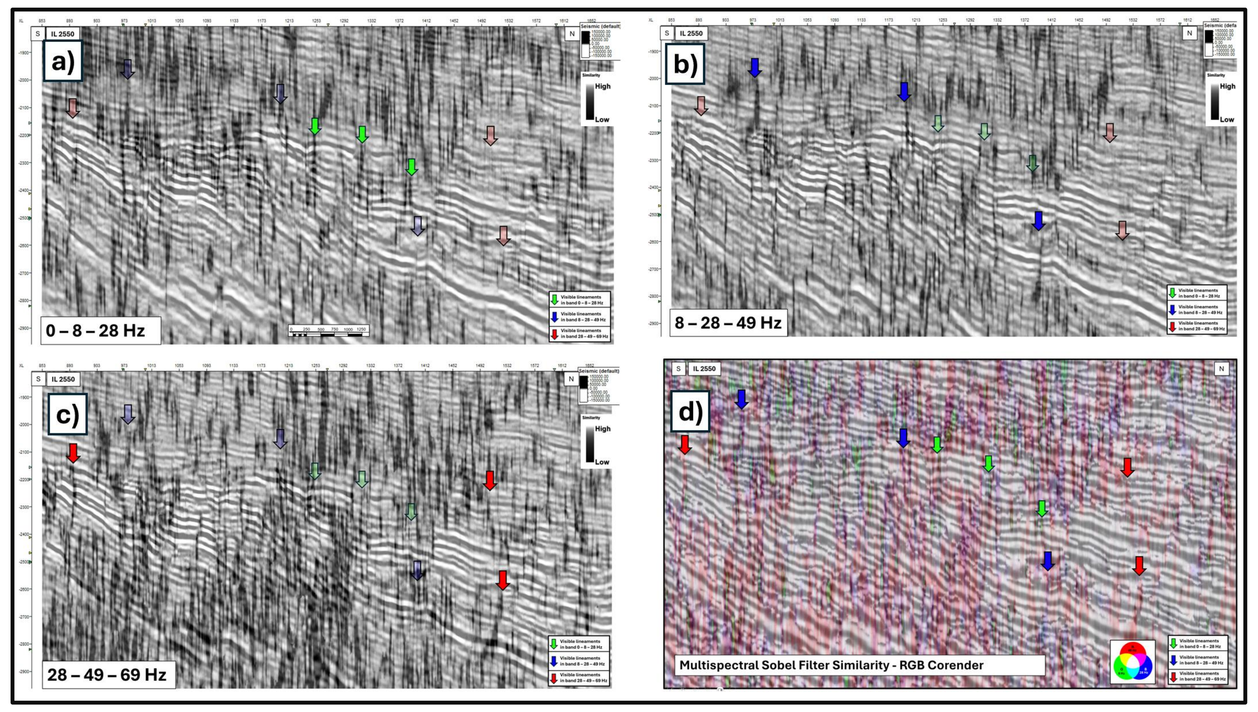


Figure 5. Spectral decomposition using Sobel similarity (8–69 Hz): individual frequency bands highlight different lineaments, while RGB co-rendering enhances their visibility and continuity.

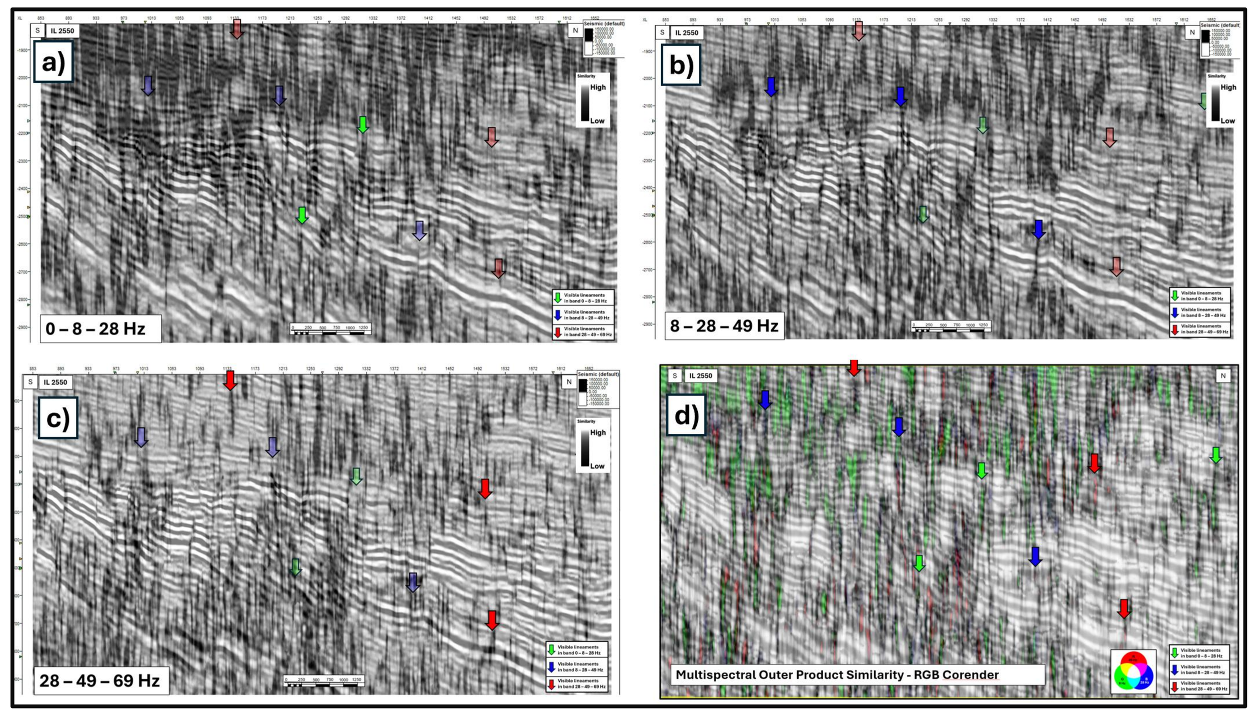
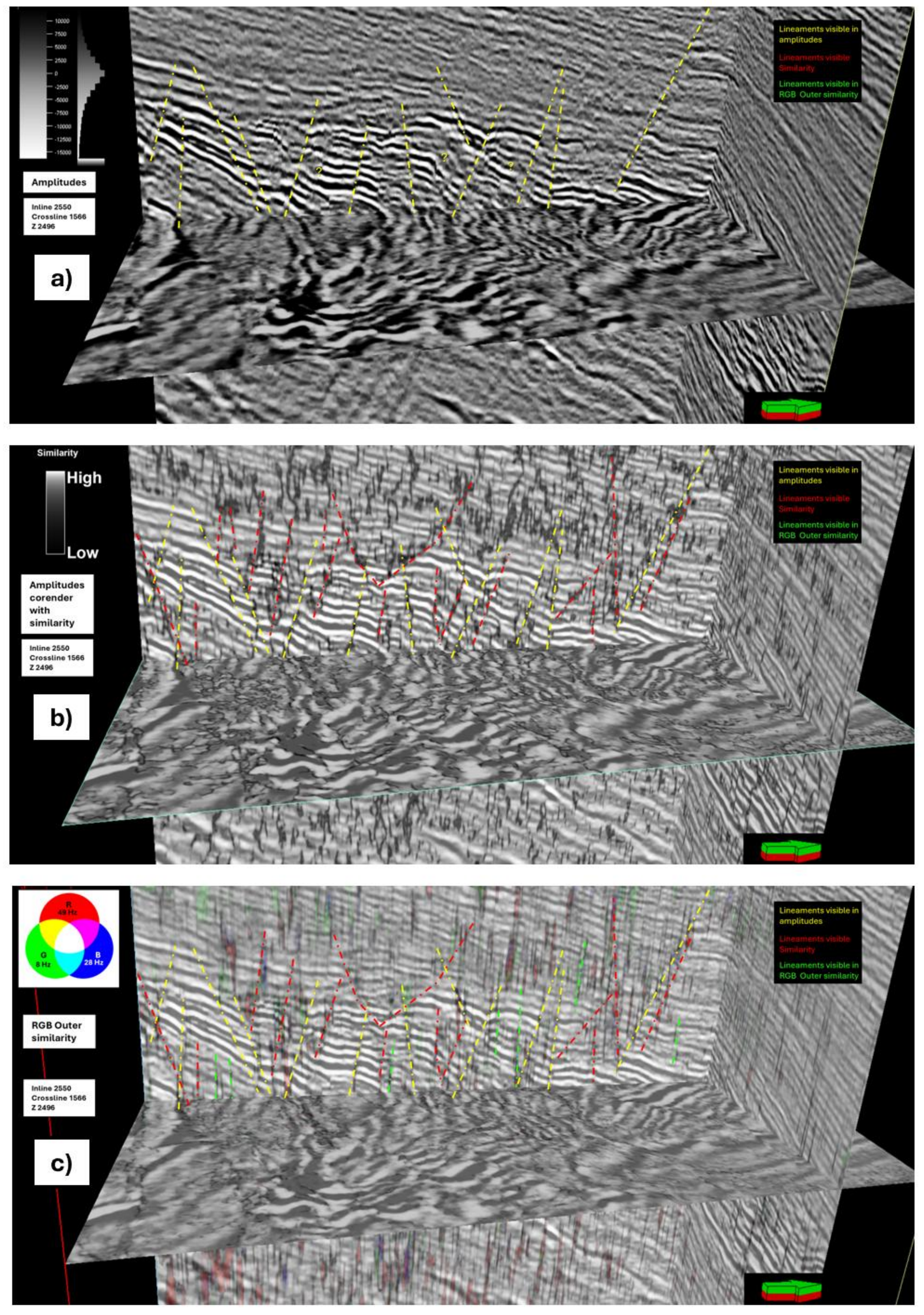


Figure 6. Outer similarity results. The attribute produces clearer and more continuous structural features, enhancing fault zones and subtle lineaments with improved contrast and reduced noise relative to Sobel similarity.

- The workflow enables filtering of seismic data and identification of relevant frequency bands.
- Noise reduction is a primary objective; however, different frequencies image geological features at different scales.
- Frequency bands should not be discarded without evaluating the potential loss of geological information.
- Different frequency volumes highlight distinct lineaments and structural features.
- Co-rendering multiple frequency volumes integrates these responses and improves structural characterization.
- This integrated interpretation reduces uncertainty and supports risk assessment for CO_2 storage reservoirs.

CONCLUSIONS



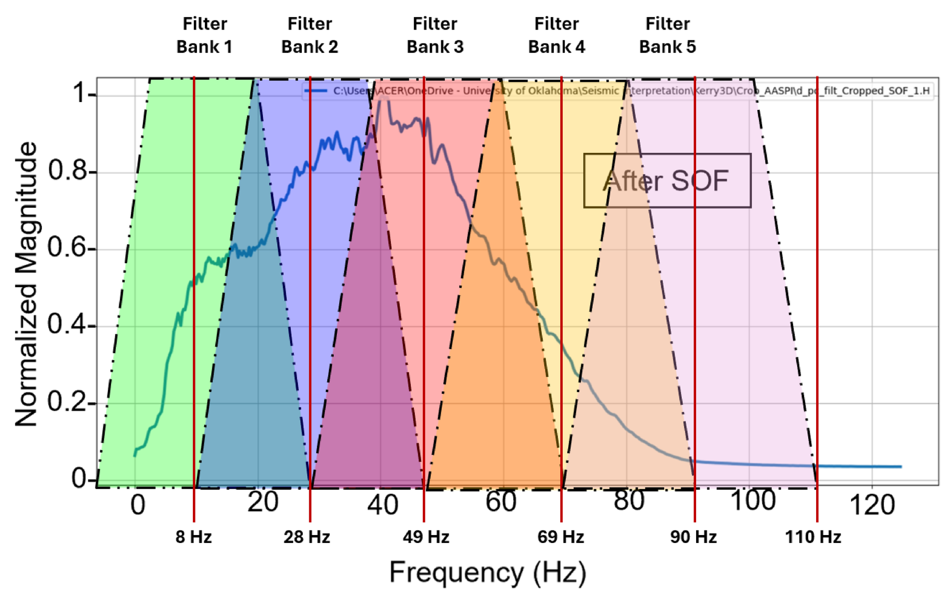


Figure 7. Frequency bands used in seismic data, with ranges selected from the frequency spectrum after SOF filtering

- This workflow can be applied to any properly processed seismic dataset.
- Data conditioning is critical, including noise attenuation and careful frequency selection to preserve geological signal.
- Different frequencies image geological features at different scales and should not be discarded without evaluation.
- Co-rendering multiple frequency responses improves characterization of the structural fabric.
- Identifying small-scale faults is critical for CO_2 sequestration, as they may act as leakage pathways or be reactivated during injection.
- Detailed structural characterization reduces uncertainty and supports safer subsurface storage as part of sustainable energy strategies.

Figure 8. 3D seismic section comparison (inline, crossline, time slice):(a) Amplitude with limited structural definition.(b) Similarity improving reflector continuity and fault visibility.(c) Outer similarity RGB highlighting small-offset faults relevant to gas storage.

FUTURE WORK

- The same seismic dataset will be used to compute the DQ Trace attribute.
- DQ Trace enhances subtle variations in rock properties and improves identification of potential reservoir sand bodies.
- The attribute supports characterization of reservoir geometry and internal heterogeneity.
- Results will be used to evaluate reservoir continuity, which is critical for porosity, injectivity, and storage capacity.
- Laterally continuous and well-connected sand bodies are essential for efficient CO_2 injection and long-term containment.
- Integrating DQ Trace with structural interpretation and other attributes reduces uncertainty and supports assessment of CO_2 sequestration viability.

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