Enhancing Crystalline Basement Characterization Using 3D Seismic Attributes and Spectral Decomposition: Unveiling Small-Scale Features and Complex Structures

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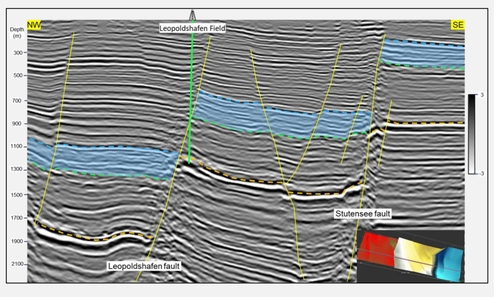
Introduction

- Advanced 3D seismic interpretation techniques improve seismic resolution, including seismic attribute analysis and spectral decomposition, has proven to be highly effective in enhancing seismic resolution and resolving complex structural and stratigraphic features.
- These methods were successfully applied in the DeepStor project to improve seismic resolution in a sedimentary basin, enabling the detection of narrow (25 m wide) paleochannels and small-scale faults.
- These methods have significant potential for crystalline basement characterization, as demonstrated in the GeoLaB project

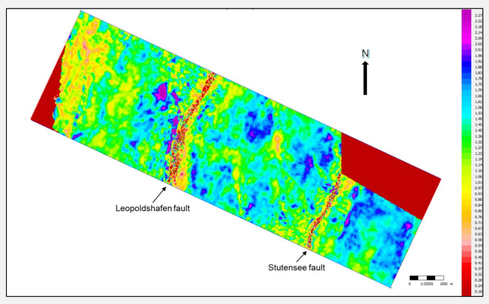
Methodology

- Conventional Seismic Interpretation:
  - Initial interpretation followed standard industry workflows, beginning with the identification and mapping of key stratigraphic horizons and structural elements.
  - Following the establishment of the structural framework, conventional seismic attribute extractions were performed to enhance the visualization of stratigraphic features within interest zone.

Define the zone

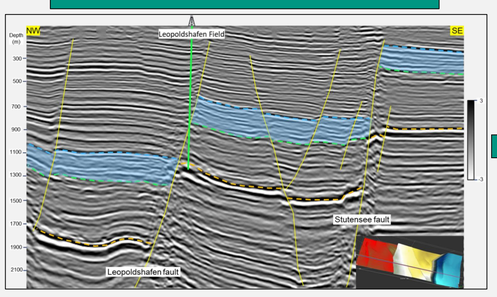


RMS amplitude

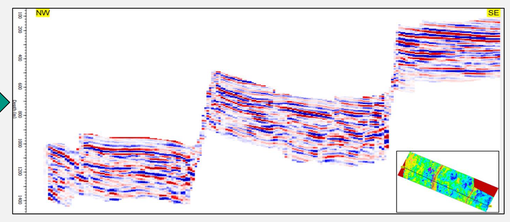


- Spectral Decomposition Implementation:
  - Spectral decomposition is a technique that decomposes seismic data into its constituent frequency components, allowing for the isolation and enhancement of features that respond differently to various frequency bands. This approach is particularly effective for detecting thin beds and stratigraphic features below conventional resolution limits.
  - Implemented a short-time Fourier transform (STFT) algorithm to generate a series of frequency slices ranging from 10 to 50 Hz at 2 Hz intervals. The STFT approach involves applying a Fourier transform to windowed segments of the seismic trace, effectively providing a time-frequency representation of the signal.

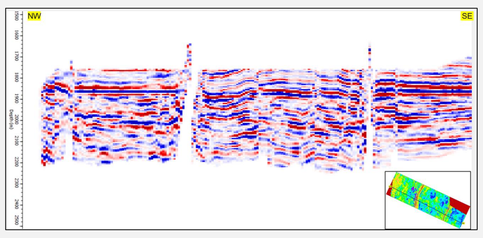
Define the zone



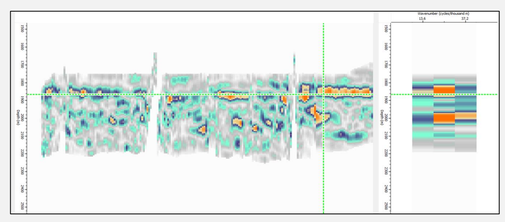
Seismic crop



Seismic flat

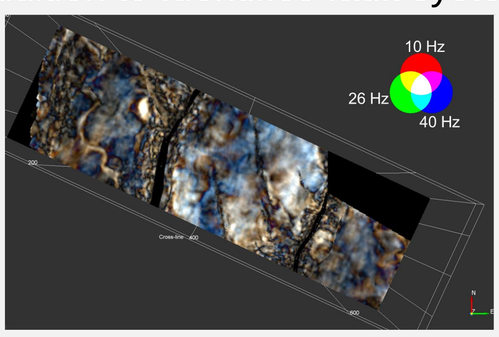


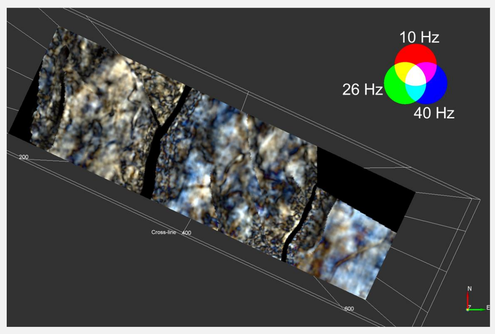
Frequency analysis



Results & Discussion

- RGB blended display: 10 Hz (assigned to red), 26 Hz (assigned to green), and 40 Hz (assigned to blue) highlights the presence of numerous meandering channel systems throughout the study area, representing the first clear visualization of these depositional elements. In addition to Identifies fault systems with throws as low as 10–15 m





- Improved seismic resolution in both sedimentary and crystalline settings.
- Spectral decomposition and attribute analysis effectively highlight small-scale geological features.
- Supports risk mitigation and exploration in crystalline basement environments.

Acknowledgment

The study is part of the Helmholtz portfolio project Geoenergy. under the topic “GEOZeit”, is gratefully acknowledged.