# Variations in Rock Strength and P-wave Velocities in a Natural $CO_2$ Leaking Fault Zone

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Accurate detection and characterisation of faults using seismic methods is critical for waste storage (e.g. $CO_2$, nuclear, landfills), tunnelling, and geothermal energy projects. In this study, we present unconfined compressive strength (UCS) and velocity measurements taken on core samples retrieved from the Little Grand Wash Fault, Utah, USA, a natural $CO_2$-leaking fault zone, to assess variations in rock strength and velocities. Together with detailed geological logging, optical petrography and CT-image analysis, we identify evidence for historic fluid flow along the fault zone and associated mineralisation. Furthermore, elastic wave velocity measurements were made during the UCS tests to detect microstructural changes and cracking within the samples during loading and evaluate if fault zone rocks exhibit different failure behaviour than rocks outside of fault zones.

Samples including Jurassic sandstones of the Summerville Formation and Brushy Basin member of the Morrison Formation were recovered from shallow (9m) boreholes on the footwall and hanging wall sides of the fault zone. Reference sandstone samples of the Morrison Formation (Salt Wash and Brushy Basin members) were collected 70km from the fault zone, away from the influence of fault-associated fluid flow.

Compared to the off-fault samples, samples from the fault zone have lower porosities and correspondingly higher densities, UCS and P-wave velocities, which is attributed to calcite cementation of historic $CO_2$ flow along the fault. The Brushy Basin sandstones in the hanging wall damage zone show the most pervasive calcite cementation, while the Summerville Formation sandstones in the footwall show varying compositions of hematite and calcite cement. There is a trend of increasing calcite cement and increasing P-wave velocities closer to the fault core, consistent with previous studies (Smith et al. 2022).

During the UCS tests, observed increases in P-wave velocity under increasing stress are associated with the closing of pre-existing microfractures which stiffens the rock matrix. With further increasing stress, new microfractures form, causing identifiable changes in the P-wave signal that can be used to forecast the rock failure (e.g. Zotz-Wilson et al. 2019). To determine minute changes in velocity within the samples, we applied coda wave interferometry to the raw waveform data recorded at regular intervals during deformation under uniaxial compression. This analysis is highly sensitive to changes in velocity and the formation of microcracks, resulting in a more precise determination of the stress threshold for damage.

Our results highlight the variations in strength and elastic wave velocity that can be found within fault zones and how the failure of recemented fault zone rocks compares to off-fault samples. Laboratory based investigations of fault zone rocks can support seismic interpretations (e.g. Liberty et al. 2022) and identifying changes in wave velocity may contribute to seismic-based subsurface monitoring of stress changes and rock failure.

## References

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