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A Novel Structural Assessment of the Robinsons River Salt Project to Support Energy Storage

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Summary

The Robinsons River Salt project targets a halokinetic salt structure in western Newfoundland and Labrador, which is being tested for suitable depth and purity for cavern development to support Underground Hydrogen Storage (UHS) and Compressed Air Energy Storage (CAES) [1]. In the summer of 2025, an Ambient Noise Tomography (ANT) survey was conducted across the project to develop a 3D shear-wave velocity model, in a novel attempt to improve the understanding of salt deposit geometry. Figure 1 presents a network of 188 tri-axial nodal seismic stations that was deployed over approximately 235 km², with an average spacing of 700 meters between nodes, to record ambient noises continuously over a span of 21 days. The resulting dataset was used to create a 3D velocity model that extends 17.50 km east-west by 9.24 km north-south, and down a depth of approximately 3.80 km, revealing shear-wave velocities ranging from 1,100 m/s near the surface to 4,450 m/s at depth. The results of the survey were integrated with previously collected gravimetric, magnetic, active seismic, and drill hole data, to provide a comprehensive subsurface characterization of the carboniferous evaporite-bearing basin.

Theory / Method / Workflow

The survey employed passive seismic imaging using fundamental mode Rayleigh waves extracted from ambient noise cross correlations. A total of 17,578 inter-station cross correlation functions were computed from vertical and radial component recordings in the usable frequency range of 0.1-5.0 Hz. Preprocessing included spectral whitening and one-bit normalization to enhance stationary noise components, followed by cross correlation in 10-minute windows and stacking across the full deployment duration [2]. Dispersion curves were extracted using frequency-time analysis, and group velocity maps were constructed through 2D tomographic inversion. A Monte Carlo-based nonlinear inversion approach was applied to reconstruct 1D shear-wave velocity profiles at each location, which were interpolated into a 3D model to quantify uncertainty and non-uniqueness. A depth-normalized velocity contrast model was computed to mitigate systematic velocity increases with depth and enhance lateral variations.

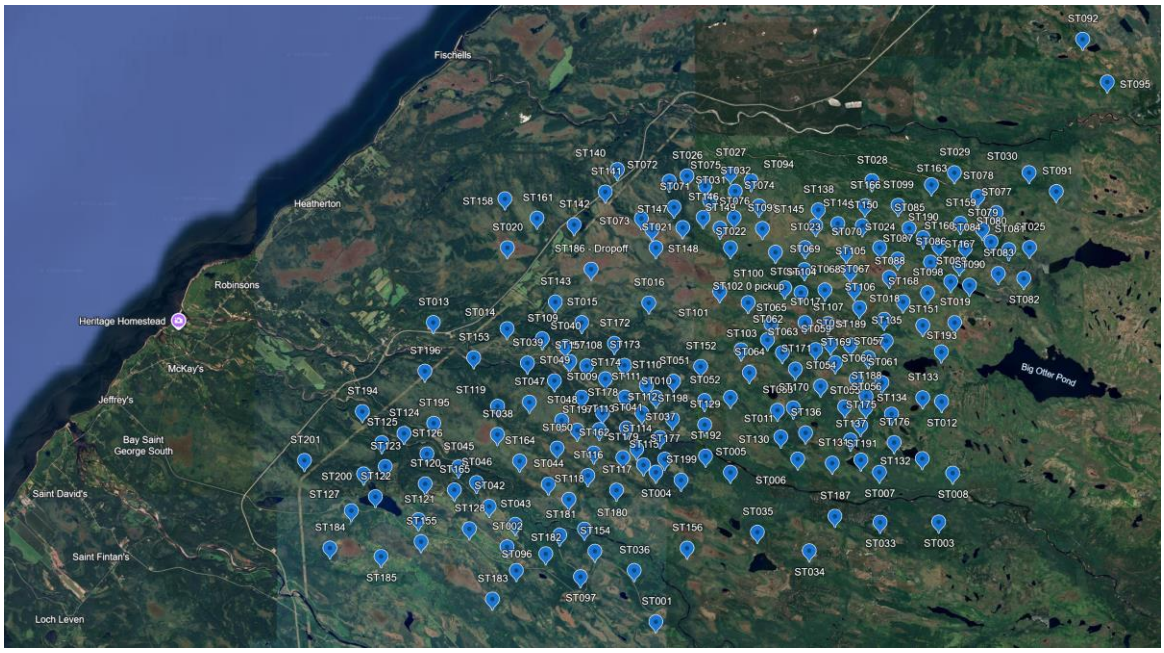


Figure 1. Arrangement of the tri-axial nodal seismic stations across the project area.

Results, Observations, Conclusions

Figure 2 presents three distinct velocity domains. In Domain 1, V_s < 1,500 m/s in the upper few hundred meters, which is attributed to open fractures. Domain 2 exhibited strong lateral variability with V_s ranging from 2,000 m/s to 4,000 m/s, constrained between a depth range of 2.0 km to 2.5 km. Domain 3 presented relatively homogeneous V_s > 4,000 m/s depths beyond 2.5 km. The contrast model revealed anomalies ranging from -40% to +109%, emphasizing sharp lateral variations and a persistent NE-trending velocity discontinuity along the eastern boundary, which has been interpreted as a major structural or lithologic boundary. Integration with gravity data showed subtle density contrasts spatially associated with the interpreted salt structures. Active seismic interpretations confirmed the spatial correlation between ANT velocity domains and salt geometry, while shallow drillhole density logs (2.3-2.6 g/cm³) provided lithologic constraints consistent with the consolidated sedimentary sequence.

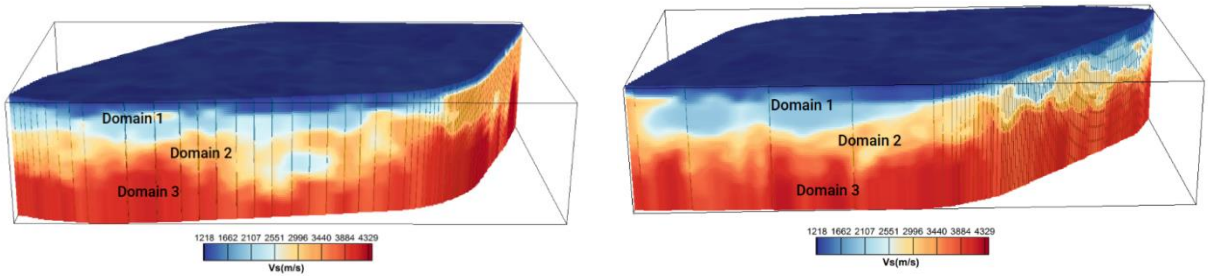


Figure 2. Shear wave velocity model with the interpreted domains, a) looking north and b) looking south. The model extends from surface down to a depth of 3.8 km.

Novel/Additive Information

This study demonstrates the first application of ANT data for characterizing subsurface salt structures in a carboniferous sedimentary basin in eastern Canada, in an assessment of cavern storage opportunities to support UHS and CAES. The integration of passive seismic imaging with gravity gradiometry and 3D density inversion represents a multi-physics approach to subsurface characterization of evaporite deposits. The research addresses a critical challenge in salt deposit imaging, where velocity overlap limits direct salt boundary delineation. The depth-normalized velocity contrast model successfully identified major structural features including basement rocks and fault zones that provide essential geological context for hydrogen storage cavern development. While gravity data delineates salt geometry through density contrasts, passive seismic provides complementary constraints by detecting microseismic activity associated with active structures, stress heterogeneities, or zones of compromised salt quality within the deposit, which are important factors for assessing long-term cavern integrity.

Acknowledgements

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