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The Role of Geophysics in Improving the Safety of Underground Storage in a Carbon-Neutral Future

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The energy transition to meet net-zero emissions by 2050 has created demand for underground caverns needed to safely store CO2, hydrocarbon, hydrogen, and wastewater. Salt domes are ideal for underground storage needs because of their low permeability and affordable costs, which makes them the preferred choice for large-scale storage projects like the US Strategic Petroleum Reserves. However, the uneven upward movement of salt spines can create drilling problems and breach cavern integrity, releasing harmful gases into overlying aquifers and endangering nearby communities. Here, we present a novel application of data-driven geophysical methods combined with machine learning that improves salt dome characterization during feasibility studies for site selection and potentially advances the effectiveness of current early-warning systems.

We utilize long-term, non-invasive seismic monitoring to investigate deformation processes at the Sorrento salt dome in Louisiana. We developed a hybrid autoencoder model and applied it to an 8-month dataset from a nodal array deployed in 2020, to produce a high-fidelity microearthquake catalog. Our hybrid model outperformed traditional event detection techniques and other neural network detectors. Seismic signals from storms, rock bursts, trains, aircraft, and other anthropogenic sources were identified. Clusters of microearthquakes were observed along two N-S trends referred to as Boundary Shear Zones (BSZ), along which we infer that salt spines are moving differentially. Time-lapse sonar surveys were used to confirm variations in propagation rates within salt spines and assess deformation within individual caverns. Seismicity along one BSZ is linked with a well failure incident that created a 30-ft wide crater at the surface in 2021. This study introduces a novel method for mapping spatial and temporal variations in salt shear zones and provides insights into the subsurface processes that can compromise the safety and lifetime of underground storage sites.