

Developing Advanced Criteria for Deep Borehole Disposal and Deep Safety by Identifying Regional Seals in the Western Canadian Sedimentary Basin through Carbon Isotopic Fingerprinting of Hydrocarbons

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Safe geological disposal strategies in the Western Canadian Sedimentary Basin (WCSB) require identification and evaluation of regional seals. The risk associated with legacy wells to safe disposal sites add relevant insights and key data for assessing potential ineffective seals, operational variables and mitigation strategies in the subsurface. A geosafety evaluation offers a unique opportunity to connect subsurface geological systems to the energy transition by leveraging extensive public data generated by over 850,000 oil and gas wells drilled across the region. These wells provide critical insights into the performance of natural barrier systems, particularly shale formations that serve as regional seals. Deep safety systems comprise the host formation, disturbed rock zones, and overlying and underlying geological units, all of which play key roles in maintaining containment integrity. Deep safety systems, including host formations, disturbed rock zones, and adjacent geological units, play roles in maintaining containment. Host formations act as primary barriers, while disturbed zones and geological units provide additional protection against breaches.

Carbon isotopic fingerprinting of hydrocarbons has proven to be a relevant tool for assessing regional seals. This technique enables the precise identification and characterization of gases from specific geological formations, yielding data on their source, fate, and distribution. In the WCSB, such applications include evaluating reservoir interconnectivity, monitoring gas mixing, and assessing the functionality of multi-seal systems. These geochemical insights not only deepen our understanding of subsurface processes, but also provide input for evaluating the viability of deep borehole disposal (DBD) systems for multiple applications.

This study integrates engineering and geoscience to develop criteria for DBD site selection. Gas isotopic analysis of surface casing vent emissions from compromised wells is employed to assess leakage depth, origin, and frequency, utilizing data from thousands of wells across Alberta. By analyzing patterns, the research identified risks to seal integrity and established geological criteria for secure disposal. Findings enhance probabilistic modeling by incorporating isotopic signatures to predict seal behavior under stress and support legacy well remediation by identifying leakage pathways for precise interventions. This study addresses seal performance and host rock feasibility, advancing safe and reliable WCSB deep disposal strategies.