Assessing the Potential of Hydrogen Storage in Salt Caverns -A Lotsberg Case Study

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Summary

Hydrogen plays a crucial role in the transition from fossil fuels to clean energy. Salt caverns have been used to store natural gas and other hydrocarbon materials for several decades [1- 3]. Also, salt caverns are the most appealing and suitable choice for large-scale hydrogen storage due to their high sealing potential and impermeability [4,5]. However, few research has investigated the possibility of underground hydrogen storage in Canada [6]. This study aims to evaluate the potential of H_2 storage in salt caverns. A combination of laboratory tests is conducted to evaluate the possibility and extent of hydrogen leakage into the cavern wall, and to investigate how salt-rock heterogeneity affects hydrogen transport. Also, a geochemical modelling is conducted to predict the reactions in H_2-brine-salt rock systems.

Theory / Method / Workflow

The subject of this study is Lotsberg Salt Formation (LSF), which is a bedded salt formation located in central Alberta. Our approach involves three main steps. First, we conduct a comprehensive characterization of the salt-rock heterogeneity. To achieve this, we use a combination of techniques, including thin-section analysis, x-ray diffraction analysis, high-resolution CT scan, and SEM/EDS analysis. Second, we evaluate the helium diffusion rate through the salt rocks under cavern operating conditions by conducting leakage tests using a custom-designed visualization cell. The aim is to investigate the effects of discontinuities such as fractures and crystal boundaries on helium diffusion rate. Furthermore, we employ geochemical models using the PHREEQC to simulate the induced geochemical interactions, predict the by-products, and estimate reaction time scales.

Results, Observations, Conclusions

Lotsberg Salt mainly consists of halite with trace amounts of carbonate impurities, while Lotsberg Marlstone comprises halite with a carbonate matrix containing carbonates, clays, quartz, and muscovite (Figure 1). The results of helium diffusion through different salt rock plugs are shown in Figure 2. Helium diffusion through pure and intact halite samples is negligible, and the micro-scale halite crystal boundaries are non-open for helium diffusion. Halite samples with macro-scale grain boundaries and carbonate impurities shows higher helium diffusion rate due to the more interconnected pore networks. The formation of secondary halite veins between grain boundaries can lead to tightly-sealed boundaries that have poor connectivity, limiting helium diffusion within the sample. Salt-rock samples with intergranular fractures show the most significant helium diffusion, suggesting the preferential diffusion of helium through these fracture pathways. The geochemical modelling demonstrates that silicate and clay minerals exposed in H_2-saturated brine maintain geochemical stability, having negligible effect on H_2 consumption. However, the presence of carbonates and anhydrite can induce the dissociation process of H_2 in brine and result in the potential production of methane and H_2S. Though hydrogen loss and by-product generation are expected in salt caverns, kinetic modeling reveals that the time elapsed before such reactions pose any concerns is significantly long. Therefore, caverns developed in salt formations with limited impurities are considered preferable options for underground hydrogen storage.

Novel/Additive Information

The research results will offer valuable insights into the hydrogen transport and geochemical reactions in salt caverns, which may have practical applications for optimizing and managing hydrogen storage.

Acknowledgements

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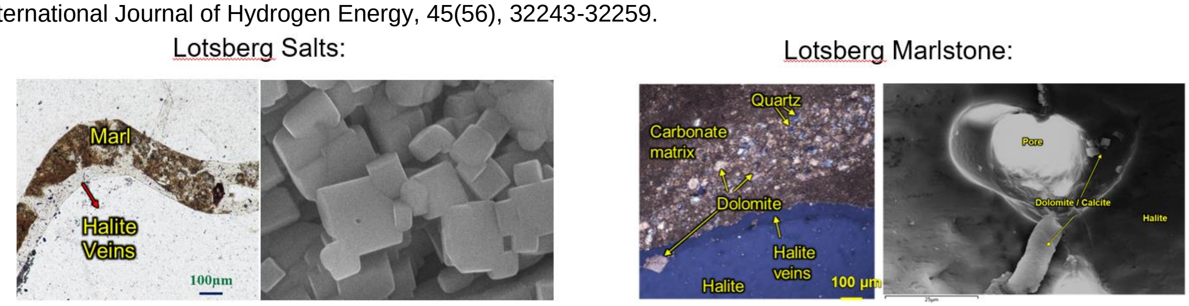

Figure 1. The sample characterization of Lotsberg halite salt, and Loteberg marlstone.

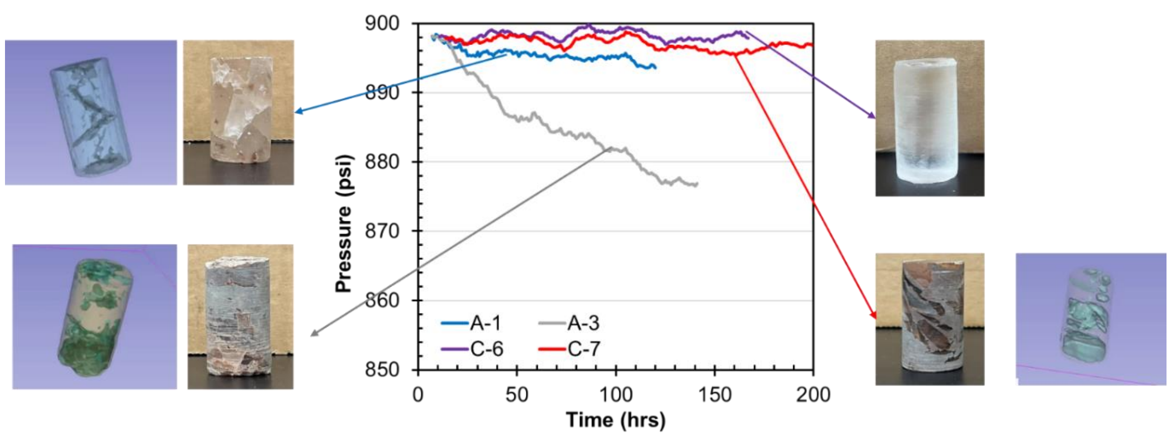

Figure 2. The helium diffusion through different salt samples with their 3-D models.