The Potential Feasibility of Underground Hydrogen Storage by the Insights From the Caprock Mineralogy Characterization: A Case Study at Robinson River

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Summary

Globally and in Canada, there is a growing focus on low-carbon hydrogen as a fuel source. One of its most compelling advantages is that, upon consumption, it does not produce greenhouse gas (GHG) emissions [1, 2]. Underground hydrogen storage (UHS) in geological formations, particularly in salt domes, has emerged as a promising strategy for large-scale energy storage due to the favorable sealing properties and structural integrity of salt formations [3, 4]. Based on the current geological and geophysical data, it is clear that the Robinson River salt has the potential for constructing salt caverns and conducting UHS [5, 6]. The purpose of this study is to evaluate the mineralogical and petrological characteristics of these salt domes, which is essential for determining their suitability for UHS applications. Currently, the results indicate that the core can be broadly subdivided into three segments: an evaporite section, a mixed section, and a salt rock section. The uppermost evaporite portion is composed almost entirely of gypsum, with the insoluble fraction exceeding 85%. By contrast, the salt rock portion is dominated by halite, with an average of 20% insoluble impurities—primarily stable felsic minerals.

Theory / Method / Workflow

In order to accomplish the objectives of this study, the workflow was divided into two investigation approaches. The first approach involved selecting specific core blocks—based on initial core observations—for thin-section preparation. These thin sections were examined under optical microscopy to gain preliminary insights into mineral types, textures, and microstructural features. Raman spectroscopy and Field Emission Scanning Electron Microscopy equipped with Energy Dispersive X-ray Spectroscopy (FESEM-EDS) were then employed to identify minerals that are not easily discernible through conventional optical methods, with Raman spectroscopy providing crucial evidence for the presence of organic matter. The second approach entailed collecting samples from intervals not used for thin-section preparation, grinding them into powders for X-ray Diffraction (XRD) analysis. This approach helped establish a mineralogical profile varying with depth. Additionally, the same powder samples were used to conduct insoluble mineral analysis, determining the percentage of insoluble minerals contributing to the salt rock texture.

Results, Observations, Conclusions

Based on preliminary observations of the Robinson River salt dome core, three lithological units—evaporite, mixed, and salt rock sections—were delineated. The upper evaporite section is predominantly composed of gypsum, with XRD results (Figure 1 A) indicating that it accounts for over 98% of the composition and the remaining fraction being anhydrite. Within the salt interval, halite (Figure 1 B-E) constitutes the principal phase, with subordinate felsic minerals (e.g., quartz, muscovite), sulfates (gypsum and anhydrite), and carbonate minerals also present. Although the overall potash mineral content is relatively low, both XRD analyses and thin-section observations (particularly those revealing sylvite (Figure 1 C-E)) confirm its occurrence. Additionally, opaque minerals (e.g., pyrite (Figure 1 F)) were observed within the impurity fraction under thin-section examination. Raman spectroscopy clearly detects organic matter (e.g., bitumen) within the halite layers. Lab tests also show that the overlying layers are largely composed of insoluble materials, insoluble percentage average around 87%, whereas halite intervals contain about average 20% insoluble, ranging from 2 wt.% to 50 wt. %.

Novel/Additive Information

This study offers novel insights through the comprehensive mineral characterization conducted, which will serve as essential references for understanding the geochemical reactivity of the salt dome's mineral constituents with hydrogen, as well as the geomechanically sealing properties of the overlying formations—both of which are critical for evaluating the feasibility and safety of hydrogen storage in these geological structures.

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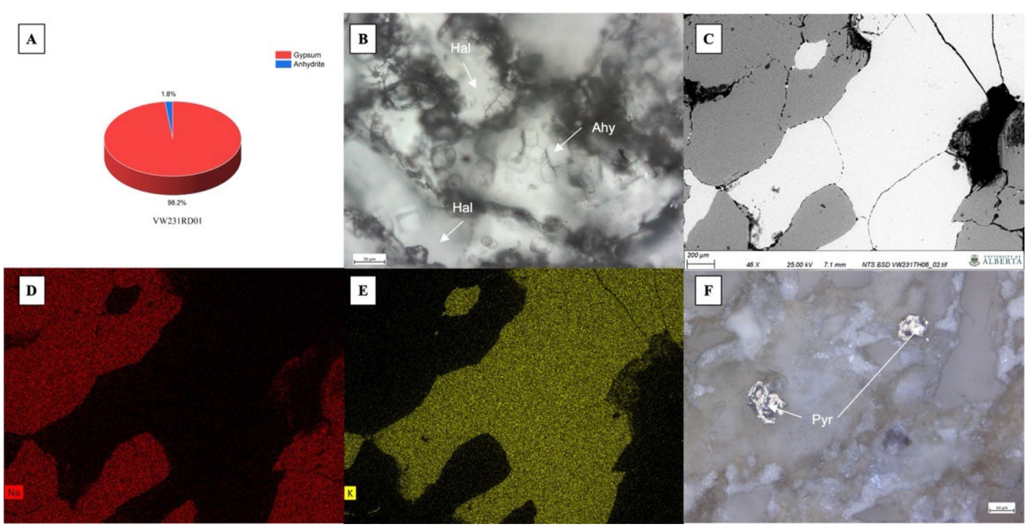

Figure 1 The sample characterization of Robinson River Salt Complex