Mineral and Textural Properties of Cold Lake Halite: Implications for Hydrogen Storage

Davood Zivar[1], Guanhua Li[1], Pavel Kabanov[2], Hassan Dehghanpour[1]
[1]University of Alberta
[2]Geological Survey of Canada

Summary

Salt solution mining in Alberta began 77 years ago, targeting bedded evaporites of the Devonian Elk Point Group. Presently, there are over 150 active caverns in the province utilized for waste disposal or cyclic natural gas storage-withdrawal [1]. A novel application of salt caverns is hydrogen storage-withdrawal, which requires significant investigation due to the high chemical reactivity and diffusivity of hydrogen [2]. Here, we examine core samples of the Cold Lake Formation (CLF), one of the untapped salt formations for hydrogen storage purposes [3]. This study focuses on heterogeneity, mineral composition, insoluble components of the halite bed, and textural properties of salt crystals; variables that are important in cavern washing designs, especially for novel hydrogen applications. The results show that the CLF has a thickness of 43m with dominantly euhedral salt crystals. The impurities within the halite interval are less than 5 wt.%. The most abundant impurities are carbonate minerals, with no detected anhydrite.

Geological context

In Western Canada Sedimentary Basin south of 60°N, cavern-purposed halite units occur in basal Devonian evaporites bundled in the Elk Point Group [1,4,5]. Salt formations in this stratal succession are bedded with no domes or diapirs, as none of these salt units extend westward into the fold-and-thrust belt of the eastern Cordillera. The thickest development of the lower Elk Point Group occurs in the Central Alberta sub-basin (CAS) – a roughly isodiametric depression in pre-Devonian paleo-relief ~350 km across (Figure 1). In main, Albertan part of CAS, the Upper Lotsberg halite member of the Lotsberg Formation is the cleanest, most homogeneous, and thickest salt bed extensively used for salt cavern emplacement [1,4]. The Prairie Evaporite Formation of the upper Elk Point Group is also solution-mined in many regions for cyclic gas storage-withdrawal and waste disposal. Halites in the Prairie Evaporite contain higher proportion of marly, dolomitic and anhydritic interbeds [1,4], limiting its use for storage of highly reactive media like H_2 gas. In Saskatchewan, the Prairie Evaporite is the only formation where storage caverns can be emplaced. Caverns there are mined in variously anhydritic halites of the lower part of the formation. The upper Prairie Evaporite in Saskatchewan and SW Manitoba contains thick sylvinite and carnallitite beds, which are high-grade potash ores reserved for potash mining. Storage caverns are not emplaced in these potash salts.

The Cold Lake is yet another halite-dominated formation of the Elk Point Group (Figure 2). Stratigraphically this unit occurs between the Lotsberg and Prairie Evaporite formations, from which it is separated by successions of red beds and carbonates. The Cold Lake contains less sulphates than in the Prairie Evaporite, and texturally it is closer to the Lotsberg halite member, the difference being overall higher proportion of marly-dolomitic impurities than in the Upper Lotsberg [1]. Although untapped for cavern storage at present, the Cold Lake Formation has to be prospected as the anhydrite-lean halite unit of broader geographic distribution than the

Lotsberg halite, including its occurrence in the northern Alberta, western Saskatchewan, and extension to the north 60°N (Fig. 2) [5,6].

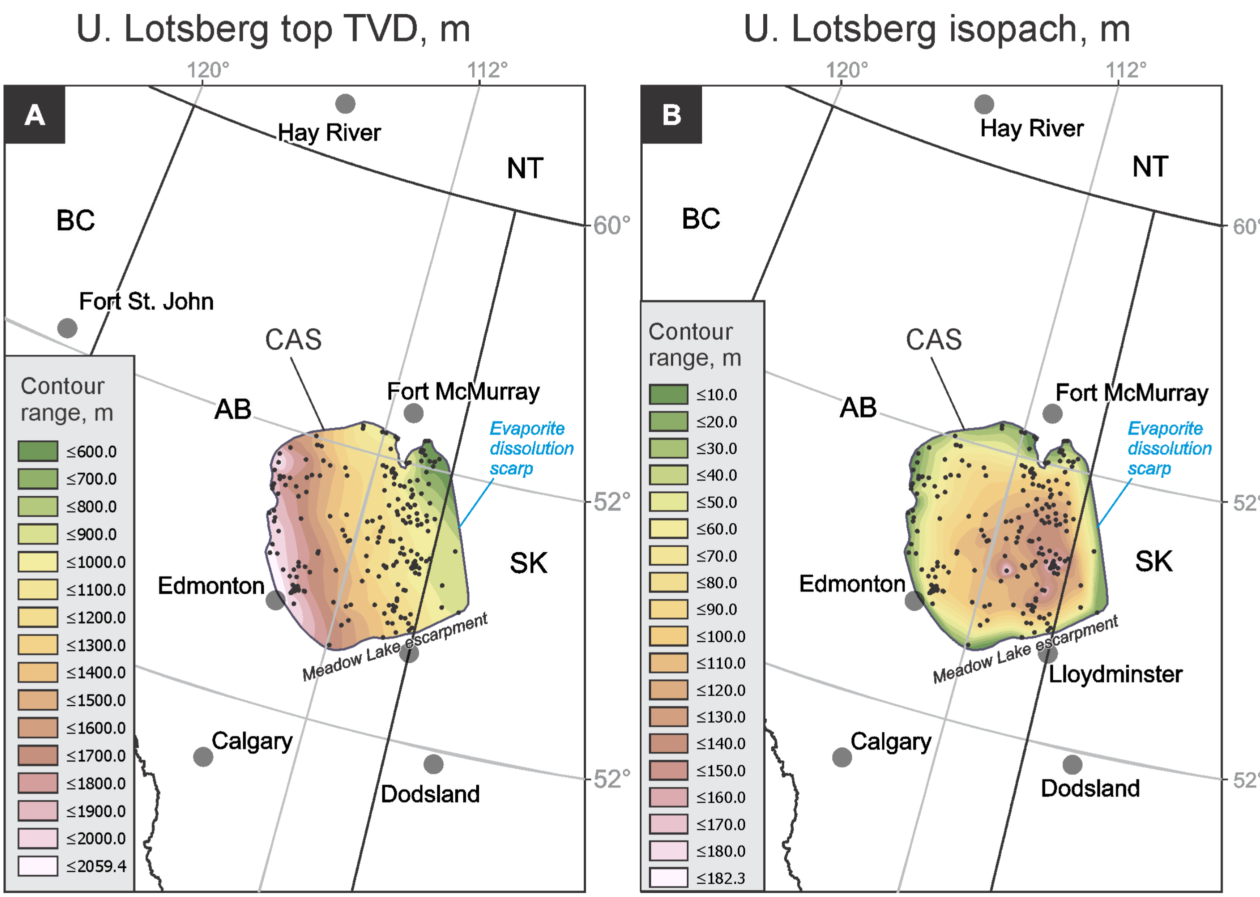

Figure 1. Upper Lotsberg halite member in Central Alberta Sub-basin (CAS): (A) depth, (B) Isopachs. Black dots are wells with non-zero thickness of the Upper Lotsberg salt. BC = British Columbia; AB = Alberta; NT = The Northwest Territories; NU = Nunavut Teritories; SK = Saskatchewan.

Theory / Method / Workflow

This study focuses on the characterization of Cold Lake Formation (CLF), a salt formation located in the eastern part of Alberta, Canada, for its potential use in underground hydrogen storage (UHS). To do so, thin section analysis and Field Emission Scanning Electron Microscopy equipped with Energy Dispersive X-ray Spectroscopy (FESEM-EDS) were conducted on the core samples received from the field to study mineralogy, inclusions, and textural characteristics of halite crystals. The mineral composition and solubility characteristics were quantified using X-ray Diffraction (XRD) and insoluble mineral percentage. In addition, Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) analysis was performed on the aqueous solution after mineral dissolution to determine the concentration of soluble ions. Then, the information obtained was used to evaluate the feasibility of hydrogen storage in CLF.

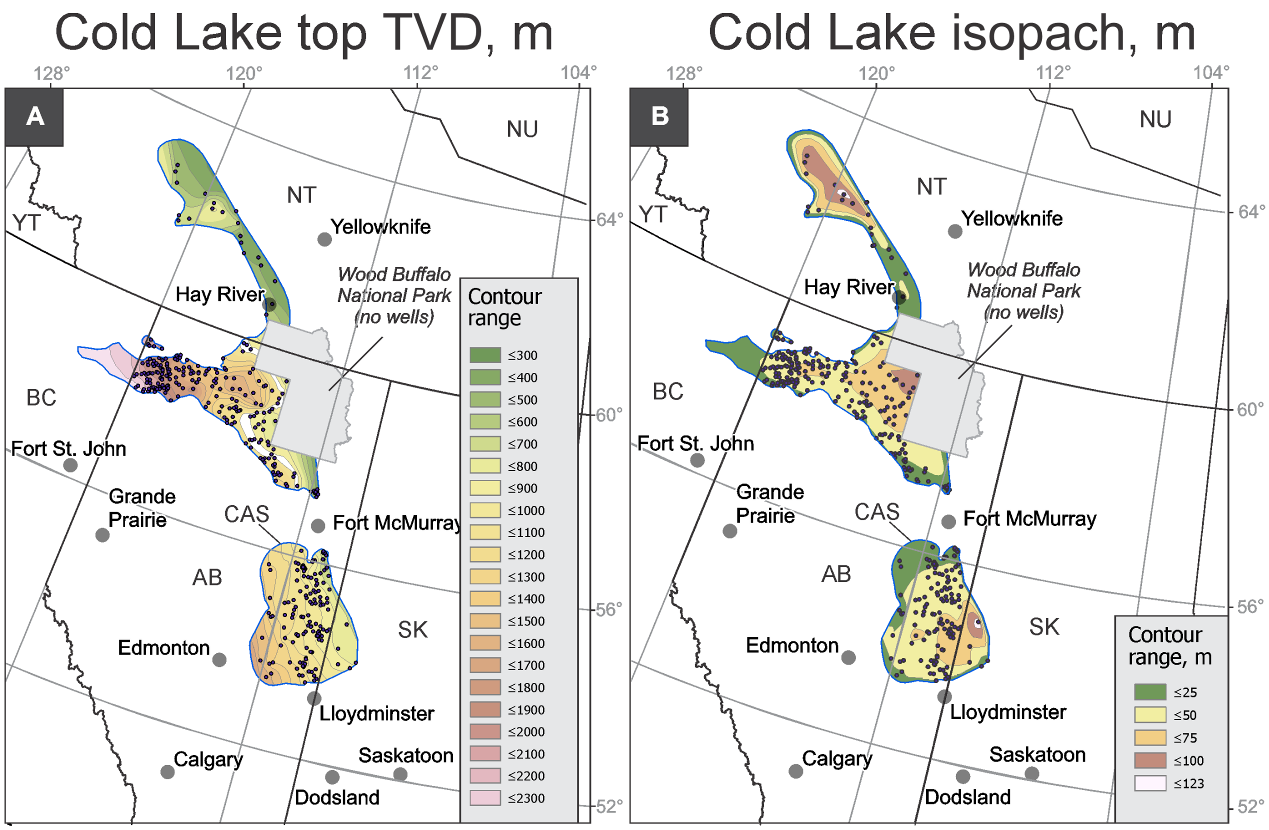

Figure 2. Maps of halite-dominated Cold Lake Formation in WCSB: (A) Depth below surface (KB as datum), (B) Isopachs. Black dots are wells with non-zero thickness of the Cold Lake salt. CAS is Central Alberta Sub-basin. Extension of thin Cold Lake tongue in northeastern British Columbia is redrawn from [5]; extension to the Northwest Territories from [6].

Results, Observations, Conclusions

The visual observation shows that the CLF is nearly 43m thick in the test core. It is overlain by the red-mottled dolomitic marlstone of Contact Rapids Formation and is underlain by nodular massive anhydrite of the upper Ernestina Lake Formation. Except for the 4.65m of basal breccia facies, the Cold Lake Formation consists of coarse to medium crystalline halite with variable admixture of dolomitic marlstone. This marlstone occurs as partings between halite crystals (Figure 3a) or as thin, discontinuous interbeds (Figure 3b). The lower part of the halite unit is the cleanest, with the least content of marlstone partings, while the percentage of marlstone partings generally increases upwards. A decrease in halite cleanness is also evident from geochemical and well log analysis. No visible gypsum is observed within the CLF.

Laboratory experiments show perfect euhedral shape of salt crystals under microscopic analysis of thin sections (Figure 3c). Fluid inclusions are also evident in these thin sections (Figure 3d). The XRD results confirm the presence of carbonate minerals as the second most abundant mineral after halite within the halite interval. The insoluble mineral experiments demonstrated that CLF halite samples have impurities less than 5 wt.%, with 99.8% contribution of Na+ and Cl- in the aqueous phase (Figure 3e).

Overall, the CLF in the studied area exhibits clean halite with negligible impurities, which reduces the risks of potential leakage and hydrogen consumption. While its thickness is less than the deeper Lotsberg Salt Formation, it still maintains potential for UHS.

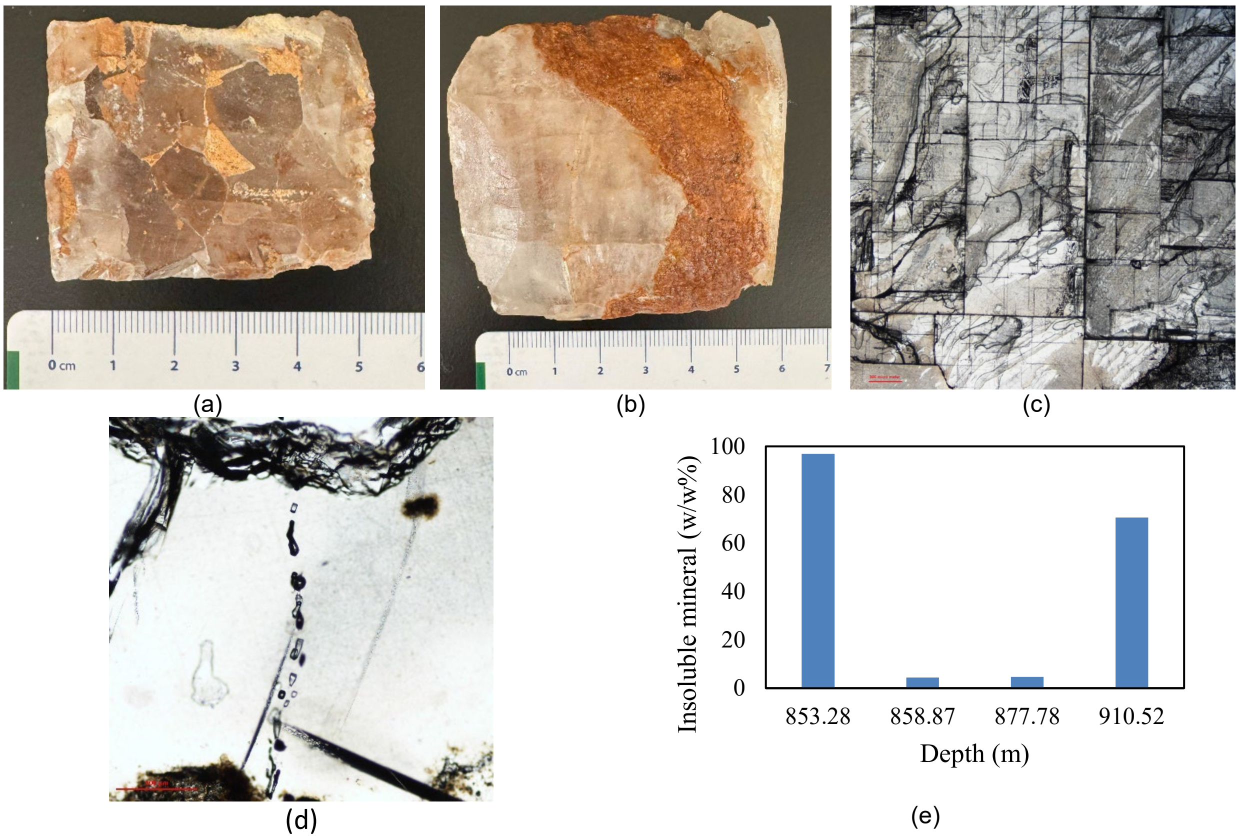

Figure 3. Marlstone occurring as partings between halite crystals (a); marlstone occurring as thin, discontinuous interbeds (b); thin section analysis showing perfect euhedral shape of salt crystals (c); microscopic image showing fluid inclusions (d); percentage of insoluble minerals within the caprock, halite intervals, and bottom of the CLF (e)

Novel/Additive Information

While the halite beds of the Lotsberg and Prairie Evaporite formations in this region are extensively exploited for salt caverns, the Cold Lake Formation did not receive much attention, despite indications of its suitability for cavern washing. This study tries to comprehensively characterize this formation through an integrated approach, which investigate minerology, heterogeneity at micro and macro scales for potential use in underground hydrogen storage.

Acknowledgements

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