

## Geological storage as a carbon mitigation option

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The most promising approach to solve the carbon problem involves widespread implementation of zero-emission power plants. These are likely to be fossil fuel-based plants with carbon capture and storage (CCS) technology. Low-emission electricity has the secondary advantage of allowing for electrification of the transportation sector, and as such can lead to very large reductions in CO<sub>2</sub> emissions if implemented at the global scale. While a variety of storage options are being studied, geological storage appears to be most viable. Injection of captured CO<sub>2</sub> into deep geological formations leads to a fairly complex flow system involving multiple fluid phases, a range of potential geochemical reactions, and mass transfer across phase interfaces. General models of this system are computationally demanding, with the problem made more difficult by the large range of spatial scales involved, and the importance of local features for both fluid flow and geochemical reactions. An especially important local feature involves leakage pathways, with one example being abandoned wells associated with the century-long legacy of oil and gas exploration and production. Such pathways also have large uncertainties associated with their properties. Therefore, inclusion of leakage in the storage analysis requires resolution of multiple scales, and incorporation of large uncertainties. Taken together, these render standard numerical simulators ineffective due to their excessive computational demands. In this lecture, I will present a series of simplifications to the governing equations that can ultimately render the system solvable by analytical or semi-analytical methods. These solutions, while restrictive in their assumptions, allow for large-scale analysis of leakage in a probabilistic framework.

## Palaeohydrology of the Mulhouse Basin: Are fluid inclusions in halite tracers of past seawater composition?

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Brine reactions processes were the most important factors controlling the major-ion evolution in the Oligocene, Mulhouse Basin (France) evaporite basin. The combined analysis of fluid inclusions in primary textures in halite by Cryo-SEM-EDS with sulfate- $\delta^{34}\text{S}$ ,  $\delta^{18}\text{O}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope ratios reveals hydrothermal inputs and recycling of Permian evaporites, particularly during advanced stages of evaporation in the Salt IV member which ended with sylvite formation. The lower part of the Salt IV evolved from an originally marine input. Sulfate- $\delta^{34}\text{S}$  shows Oligocene marine-like signatures at the base of the member (Fig.1). However, enriched sulfate- $\delta^{18}\text{O}$  reveals the importance of re-oxidation processes. As evaporation progressed other non-marine or marine-modified inputs from neighbouring basins became more important. This is demonstrated by an increase in K concentrations in brine inclusions, Br in halite and variations in sulfate isotopes trends and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios. The recycling of previously precipitated evaporites was increasingly important with evaporation. Therefore, regardless of the apparent marine sequence (gypsum, halite, potassic salts), the existence of diverse inputs and the consequent chemical changes to the brine preclude the use of trapped brine inclusions in direct reconstruction of Oligocene seawater chemistry.

**Figure 1:** SO<sub>4</sub>- $\delta^{34}\text{S}$ ,  $\delta^{18}\text{O}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope trends.

