# Controlling factors of underground hydrogen storage injection and production profiles in braided-fluvial reservoirs

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Project ADMIRE

## Introduction

Hydrogen is superior over electricity in terms of transporting and storing renewable energy. Underground hydrogen storage (UHS) is the only known large-scale hydrogen storage technology. However, due to the lack of operational experience on handling hydrogen in subsurface and fossil fuel system, the feasibility and risks of implementing UHS in porous reservoirs are still unclear. One of the very first step to investigate the feasibility of UHS is to assess its potential injectivity and productivity. Therefore, this study uses data from depleted gas fields and laboratory to find controlling factors that affect UHS injection and production profiles in braided-fluvial reservoirs.

The results of this study provide fundamental understanding on UHS projects in high sand-to-gross ratio reservoirs, facilitating techno-economic assessment of potential UHS projects based on various geological characteristics.

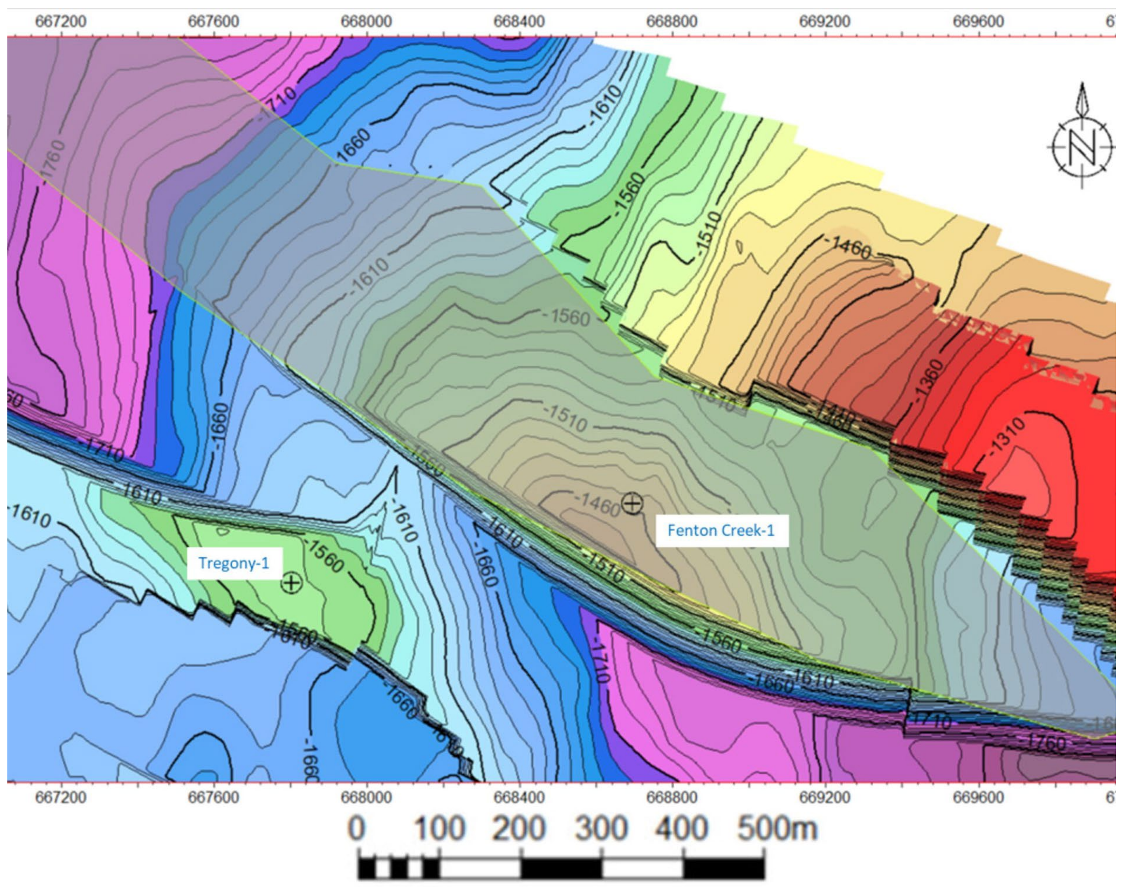


**Figure 1:** Areal view of contour map of Fenton Creek gas reservoir, the origin of structure model and data; the gas reservoir region is shaded in grey and the Fenton Creek-1 production well is marked by a cross.

## Method

Generic braided-fluvial water-gas reservoir model is built based on data from fields, Victoria Gas program, and ADMIRE group:

- Recently measured hydrogen-water relative permeability data (including imbibition);
- Reservoir structure from geological models built in Victoria Gas;
- Well log, petrophysical data, and production history from the fields.

We set up a series of simulation experiments to conduct sensitivity analysis on the potential controlling factors of injection and production profiles of UHS in gas reservoirs. Parameters investigated including:

- Relative permeability models (including imbibition);
- Reservoir formation structure (dip angle and compartmentalization area);
- Injection and production rate.

**Hydrogen gas mixing with other gas is nearly inevitable and it is expensive!**

- Pure hydrogen storage in subsurface does not show economical advantages.
- Nowadays, pilot UHS field projects are conducted as the form of hydrogen-X gas mixture storage.
- Carbon dioxide or connate methane acting as cushion gas may also lead to gas mixing.
- Gas mixing will decrease the hydrogen fraction in produced stream. The production would be disturbed and expensive gas separation and processing will be required.

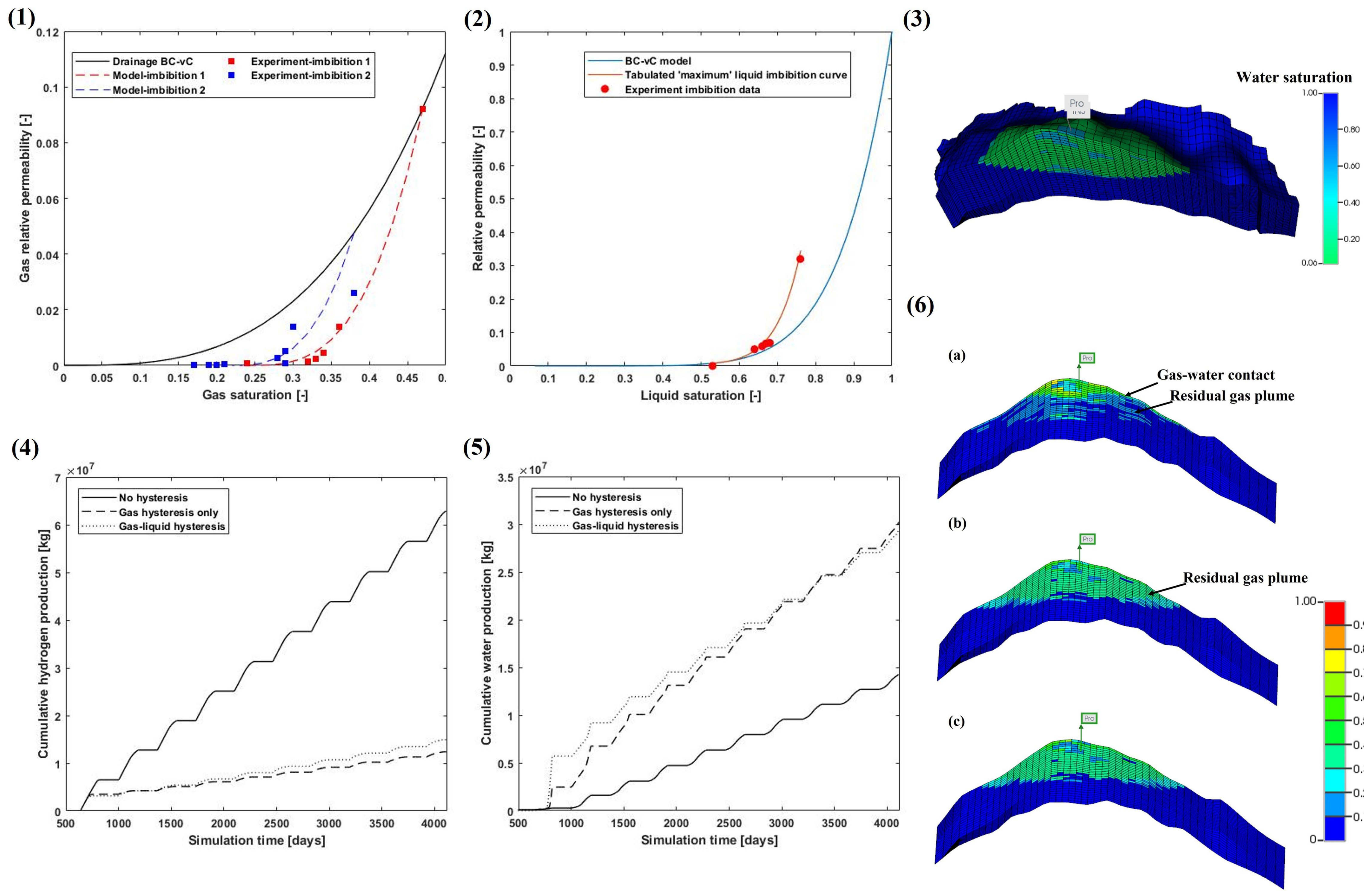


**Figure 2:** (1) and (2) Experiment measured hydrogen-brine relative permeability show very low gas relative permeability and large liquid relative permeability with strong hysteresis effects; (3) 3D view of water saturation map of generic gas reservoir with high sand-to-gross ratio; (4) and (5) hydrogen and water production history during 10 UHS cyclic operation, gas relative permeability hysteresis has negative effects on injectivity and productivity, while liquid hysteresis resolves this issue by improving the liquid displacement by injected hydrogen, resulting in more cumulative hydrogen production with less water production by the end of 10th cycle; (6) hydrogen gas saturation map by the end of 10th cycle without considering hysteresis (a), considering only gas hysteresis (b), and considering both gas and liquid hysteresis (c).

## Results

**In braided-fluvial reservoirs, relative permeability hysteresis and reservoir structure are crucial for UHS injectivity and productivity.**

Through simulation experiments, gas and liquid relative permeability hysteresis are found to affect the injectivity and productivity of UHS through different mechanisms. Reservoir formation structure is the determining factor of system correlations. Litho-facies distribution will only make considerable effects in certain structures.

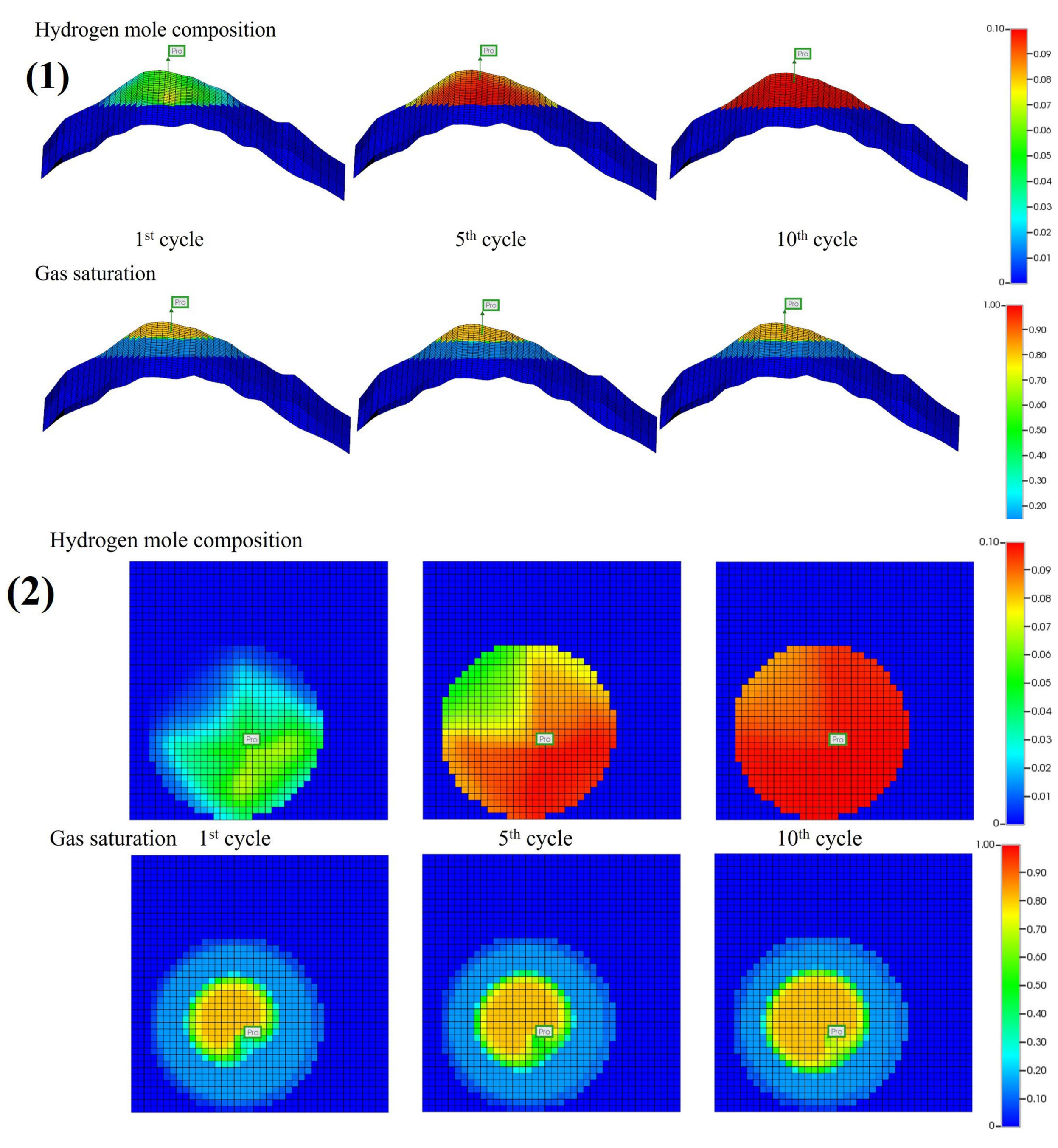


**Figure 3:** (1) Gas composition and saturation map at end of 1st (left), 5th (middle), and 10th (right) cycle in structure with large anticline dip, where connate methane gas is nearly produced out completely after 10 cycle; (2) Gas composition and saturation map at end of 1st (left), 5th (middle), and 10th (right) cycle in structure with same OGIP and smaller anticline dip, where connate methane will still mix with stored gas after 10 cycle.

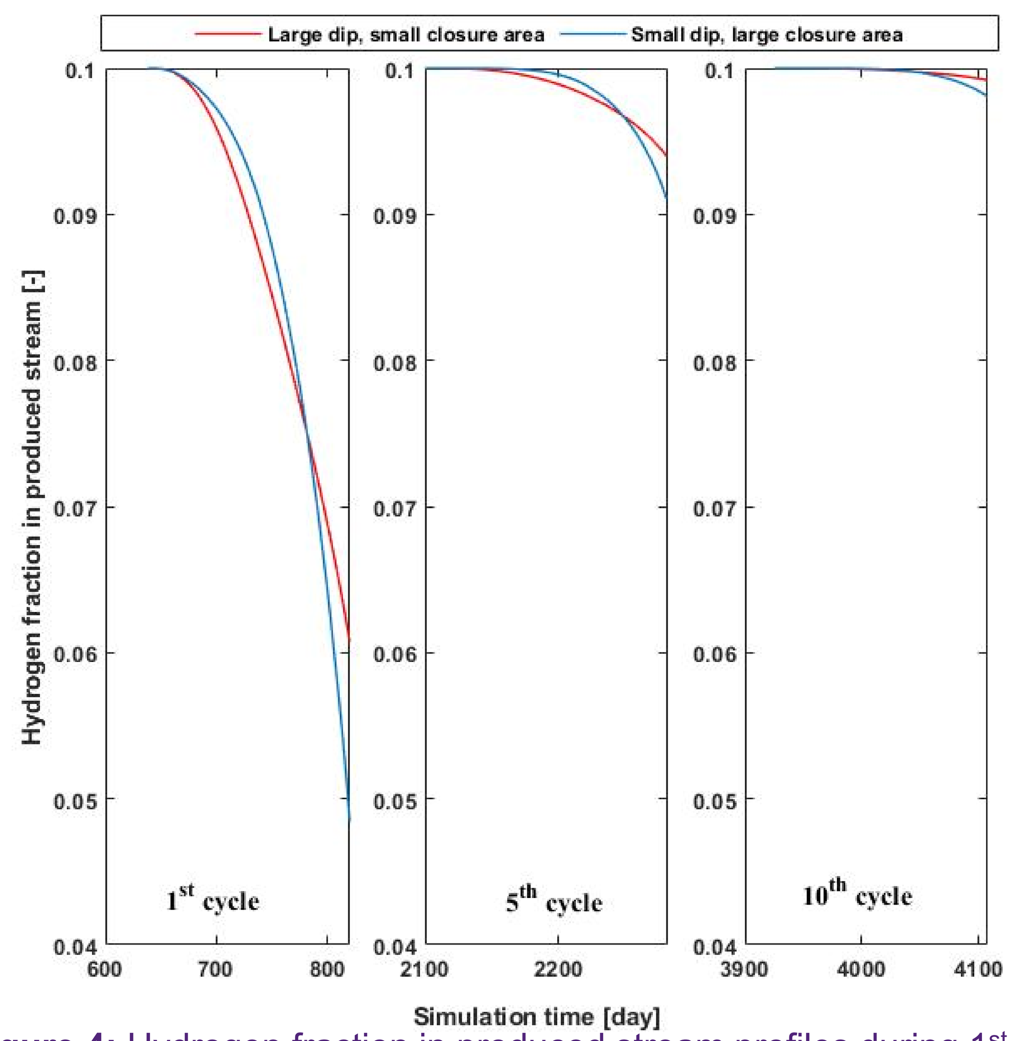


**Figure 4:** Hydrogen fraction in produced stream profiles during 1st (left); 5th (middle); 10th (right) cycle; injected hydrogen fraction is 0.1.

## Conclusions

Through simulation experiments, we find relative permeability and formation structure are controlling factor to the injectivity, productivity, and gas mixing process during UHS cyclic operations.

1. Gas relative permeability hysteresis limit the variation range of gas saturation and pressure, making negative impact on injectivity and productivity.
2. Liquid relative permeability resolve the issue by improving the liquid displacement by injected hydrogen gas. Such effects will increase the injectivity and productivity when gas relative permeability is large enough to provide corresponding gas saturation and pressure variation range.
3. Formation structure is the controlling factor of system correlations and subsequent gas mixing process during UHS. In contrast, effects from litho-facies distribution pattern will be considerable only in certain structures.

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