Three dimensional physical benchmark experiments to test variable-density flow models

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Extended Abstract by
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Motivation

- Numerical codes have to be tested
- Are the experimental results good enough for benchmarking?

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- Introduction
- The laboratory tests
- Results
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Introduction:

- A Nuclear Magnetic Resonance Imaging (NMRI) technique was applied
- Experiment is based on a stable layering of the saltwater
- Two experiments were conducted with 1 % (*saltpool_1*) and 10 % (*saltpool_10)* salt mass fraction

The laboratory tests

There are three time phases in this experiments:

<u>Saltwater injection phase:</u>

- 4 openings in the top were opened
- Outlets were fixed at identical pressure level
- For recharge of the saltwater used O_5

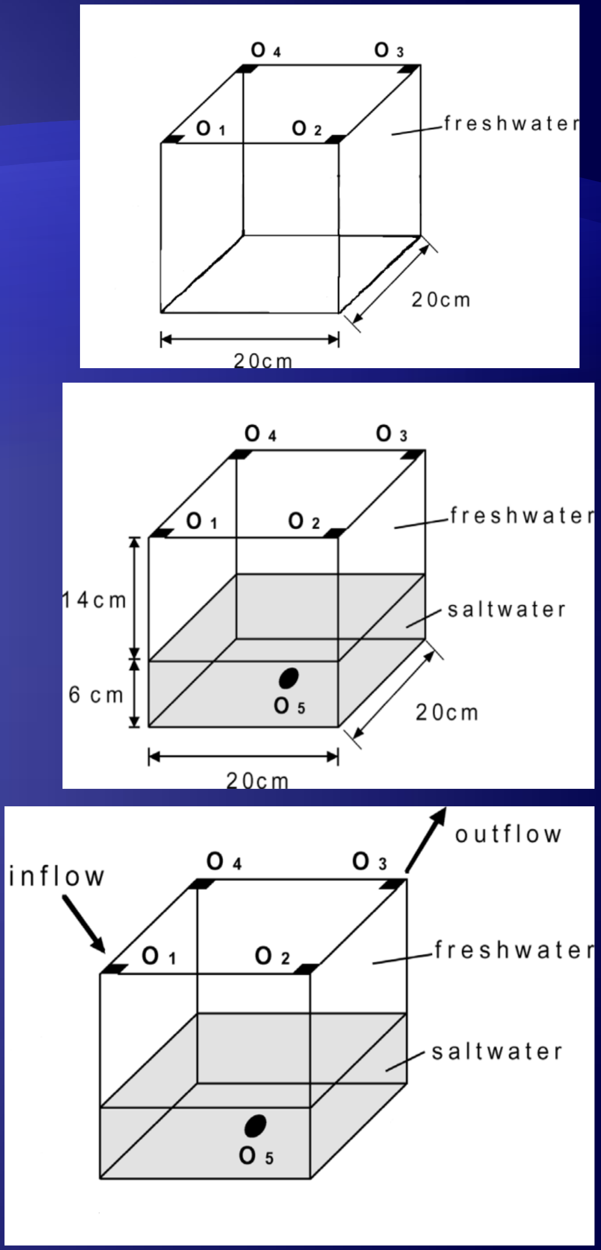

Fig. 1,2,3 Schematic of the set-up (4)

The laboratory tests

Equilibration phase:

- The inflow and outflow were stopped
- Duration of this phase was about 30 minutes

Main phase:

- 2.5 hours inflow by O_1 and outflow by O_3 of the freshwater were applied
- Volumetric flux could be applied for measuring of the discharged water

Results

NMRI experiment saltpool_1:

- Due to new pressure conditions the saltwater body pushes down
- Then below the outflow increasing upconing happens
- Simultaneously interface under the inlet slowly moves down
- After about 20 minutes in the 3 phase upconing reaches maximum
- During the 3 phase the amount of salt remaining 50 % of initial amount

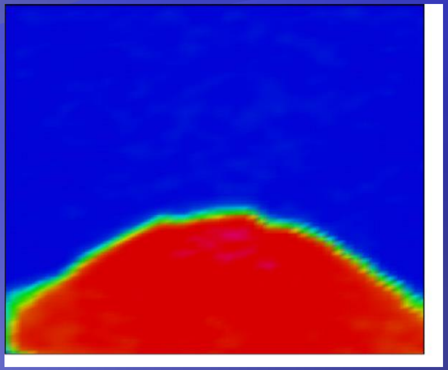

Fig. 2. Evolution of the measured relative concentrations in a vertical diagonal cross-section. 1 phase (4)

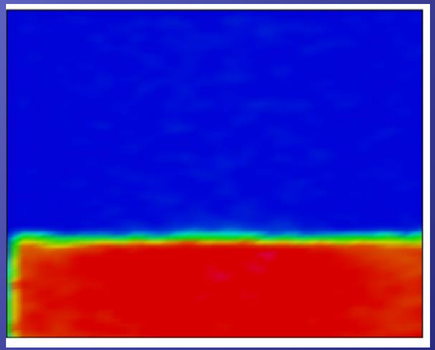

Fig. 3. Evolution of the measured relative concentrations in a vertical diagonal cross-section. 2 phase (4)

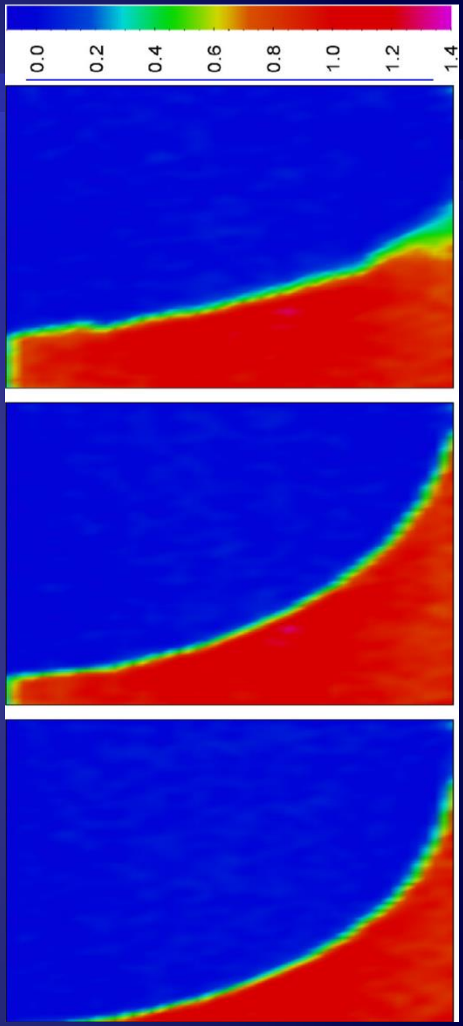

Fig. 4. Evolution of the measured relative concentrations in a vertical diagonal cross-section. 3 phase (4)

Results

NMRI experiment saltpool_10:

- The saltwater spreads to form horizontal layer
- The actual vertical changes smaller than in the former case
- Changing tendency does not continue after some minutes
- No upconing takes place
- the amount of salt decreases by 3 %

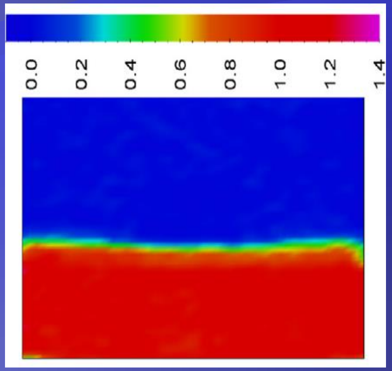

Fig. 5. Evolution of the measured relative concentrations in a vertical diagonal cross-section. 1 phase (4)

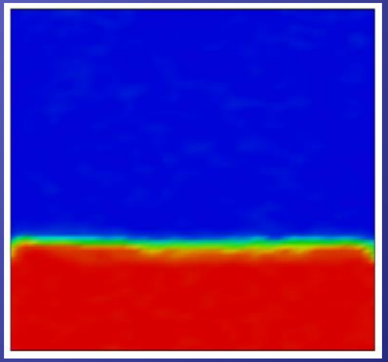

Fig. 6. 2 phase (4)

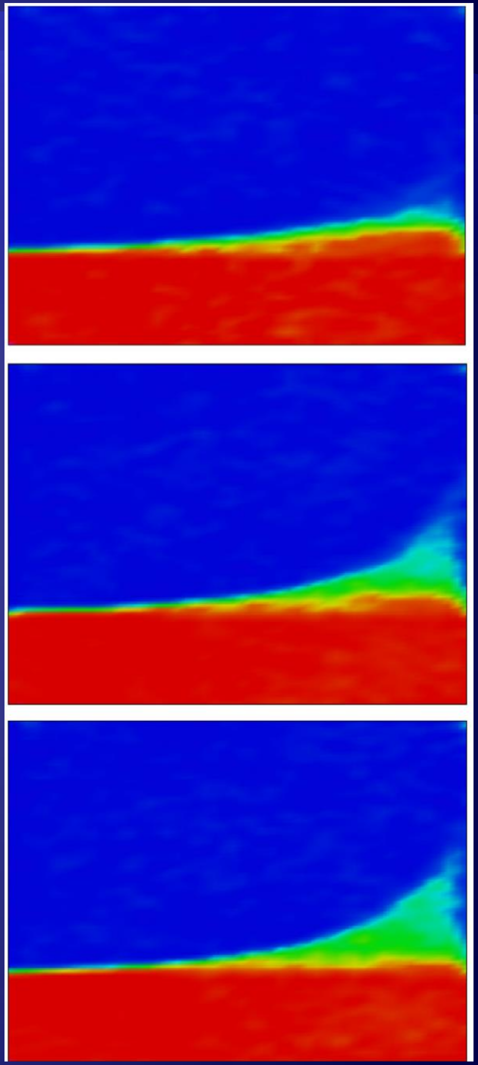

Fig. 7. 3 phase (4)

The numerical model

- The code used in this study for numerical simulation is FEFLOW
- The numerical results are comparable with experimental results

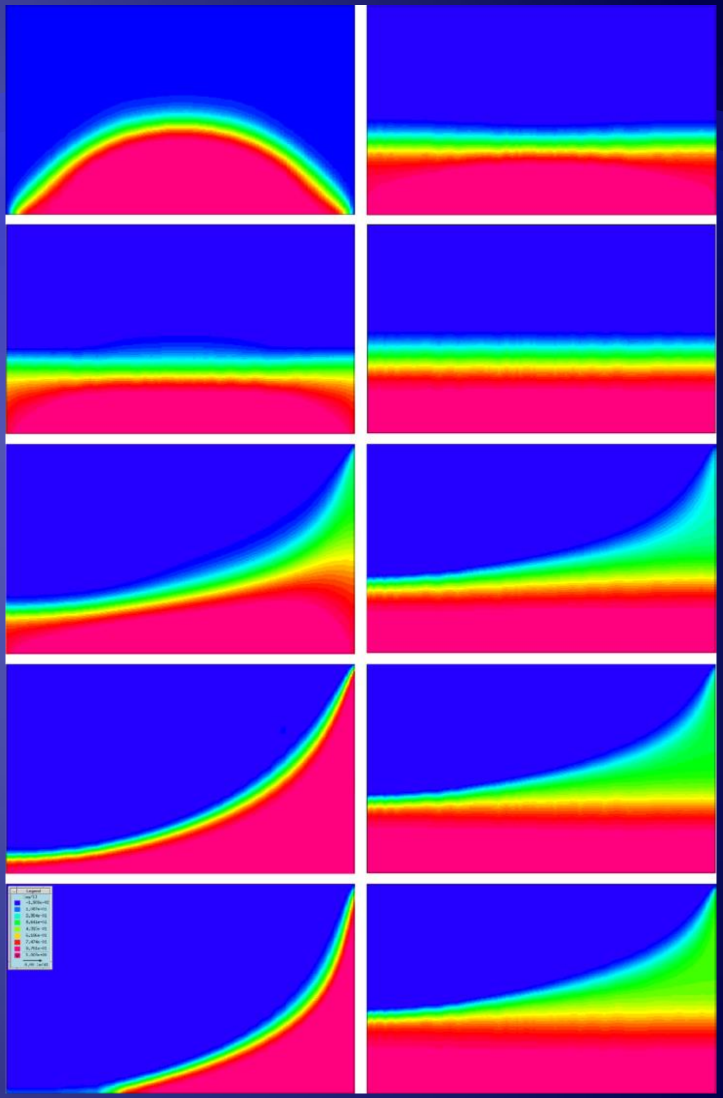

Fig. 8. Evolution of the distribution of relative concentrations in a vertical diagonal cross-section. Left simulation of saltpool_1, right simulation of saltpool_10. Times are the same as the one of the NMR images.

breakthrough curves

- The measured concentration much smaller than the initial saltwater
- This is the fact of the increasing significance of density effects

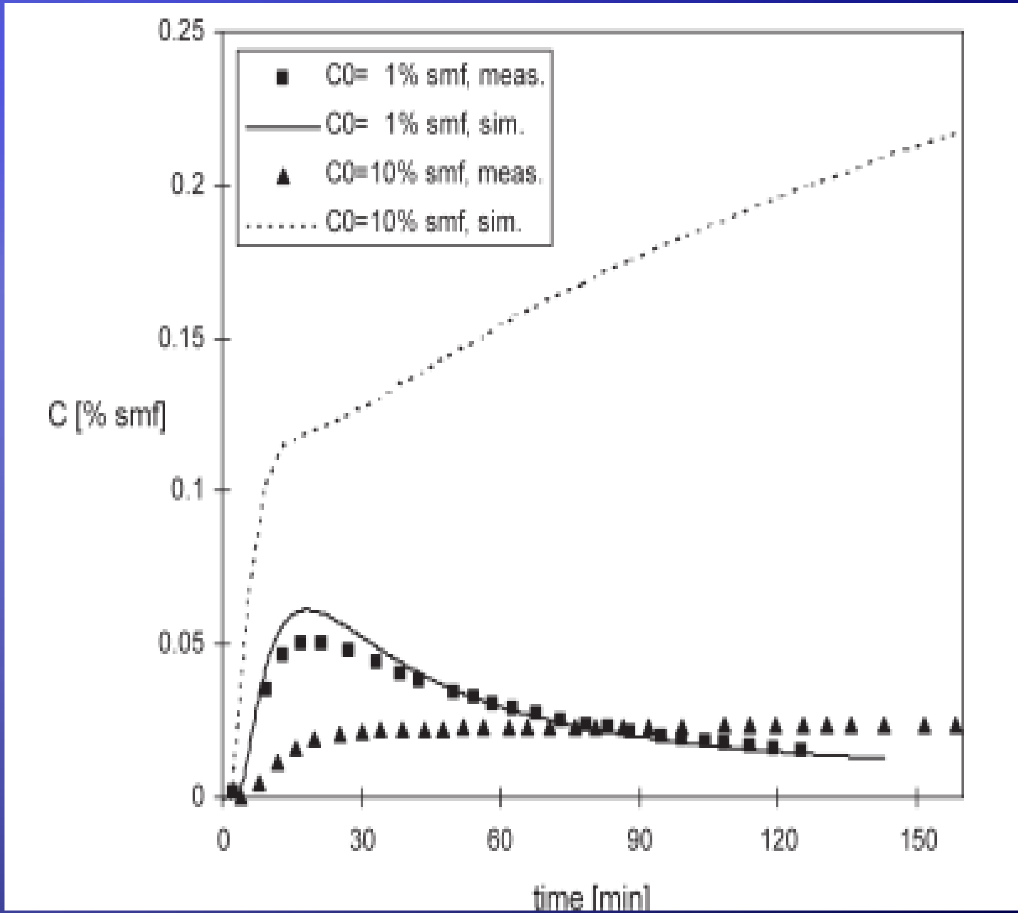

Fig. 9. Comparison of measured and simulated breakthrough curves for the saltpool_1 ðC ¼ 1% smfÞ and saltpool_10 experiments ðC ¼ 10% smfÞ:

Conclusion

- Due to geometry and homogeneity of this experiment the set-up was simple
- The outcomes are suitable for benchmarking of variable-density flow codes

References

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Thank you for attention!