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Investigation of pore-scale evaporative drying, salt precipitation and crystallization migration in CO2 injection process by a lab-on-a-chip system

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The current research work mainly focuses on the NaCl-based formation brine, and the influence of different types by formation brine on the salt precipitation have not yet been investigated. Also, the damage effect of local salt crystals on the pore structure and the migration mechanism of salt crystals after precipitation remains unclear. Based on this, this study aims to investigate the effect of different brine types on salt precipitation and migration in CO2 injection process.

In this study, a pore-scale CO2 displacement experimental study was performed using a visualized microfluidic model. Dry CO2 was injected into homogeneous and heterogeneous microchips saturated with different simulated formation brine solutions (NaCl/CaCl2/NaCl-CaCl2) at a set flow rate. Then, the two-phase flow, water evaporation, salt growth, crystallization and migration processes in the pore scale were observed under brightfield imaging using advanced polarizing microscope and X-ray microtomography imaging technology. Finally, fluorescence and transmission imaging techniques were used to clarify the distribution of salt precipitation and to quantify the amount of salt crystal.

The results indicated that the brine after CO2 flooding formed four types of irreducible water, which are liquid bridges, domes, connected liquid pools and independent liquid pools. With the increase of CO2 displacement volume, cubic regular crystals and irregular microcrystals formed inside the chip saturated with NaCl solution, which is consistent with the existing literature research. However, in our study, we also observed a new form of salt precipitation—salt bridge aggregates. Compared with the above two salt precipitation forms, salt bridge aggregates are more likely to block the pore structure, thereby affecting the permeability of the near-wellbore area. In contrast to the chip of saturated with NaCl solution, the chip saturated with CaCl2 solution did not observe an obvious solid-phase crystal structure. However, we observed an unprecedented phenomenon—the thickness of the water film was significantly reduced, and finally viscoelastic water film salt and aggregates were formed. In addition, the results of fluorescence quantification of salt crystals also observed the self-enhancement effect of salt crystal growth and the water film salt transport effect, which synergistically strengthened the precipitation rate and amount. This study comparatively analyzes the influence of brine type on salt precipitation, which provides new insights for in-depth understanding of the effect of salt precipitation on CO2 injection capacity.

We provide new insights into the dynamics of pore-scale salt precipitation through visualized microfluidic experiments and identify possible explanations for the large-scale salt precipitation observed in situ. In addition, the salt precipitation mechanism and migration characteristics of different brine types may provide new suggestions for future numerical simulation research, and provide criteria for accurately predicting the distribution of salt precipitation and its impact on reservoir physical properties.

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References

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