Direct measurement of in-situ hydrogen-water-quartz system relative permeability for Underground Hydrogen Storage in A Depleted Gas Reservoir

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Abstract. Underground Hydrogen Storage (UHS) is considered a long-term storage solution which allows excess energy developed from renewable energy sources, such as solar PV and wind turbines, to be stored in the subsurface and retrieved when energy demand increases. Research into UHS has been increasing in recent years. Petrophysical properties of hydrogen interacting with fluid and solid in subsurface porous media, such as wettability, interfacial tension and relative permeability have emerged to provide a practical basis for simulation models. Our work elucidates for the first-time, direct measurement of in-situ wettability during co-injection core floods with hydrogen and water. Analysis of micro-CT images coupled with MICP and simulation data has enabled a thorough and accurate investigation of saturation in the bentheimer core. Relative permeability curves have been validated with laboratory experiment, direct simulation on micro-CT images and simulation using MRST, a multiphysics simulation platform which has been used to implement multiphase flow in porous media. The bentheimer core sample used is representative of many target formations for UHS particularly depleted gas reservoirs and aquifers. We have developed site-specific models using our direct petrophysical measurements to analyse the practical application of UHS at the field scale with simulation models in MRST. Our results have allowed us to reliably predict the amount of hydrogen that can be stored and retrieved in the cyclical storage process and to quantify expected rates of injectivity and deliverability during operation. They also demonstrate the significance of depleted gas reservoirs for the energy transition and their use for storage of hydrogen at a large scale.