Introduction

Jianghan Basin is one of the target CO₂ storage sites. However, the salinity of the formation water in Jianghan Basin is higher compared to other places. This paper uses numerical simulation to highlight the salinity impact affecting the dry-out and precipitation while injecting dry supercritical CO₂ into Jianghan basin (China). The aim of the present study is an investigation of the aspects of salt precipitation in the vicinity of a CO₂ injection well, as induced by formation dry-out from water dissolution into the flowing CO₂ stream. The Jianghan Basin formations properties were used. In order to assess the effects a 1D model developed was considered to be a homogeneous sandstone of about 100 m thickness. Then a number of sensitivity simulations were performed to analyze the impact. The 2-D model results showed that the effects of gravity override on gas saturation distributions were strong and also reflect the effect. More details and mechanisms are needed to be explored in future’s research.

Study Area

The Jianghan Basin lies in the south-central part of the Hubei Province, the Jianghan Plain between Yangzi River and Hanhui River, west to Yichang city, east to Yingcheng city, south to Huanghai city, and north to the north of Jiangzhou city (Fig 1). It is a salt-lake rift basin developed on the Zhangyangzi palaeotopography during the Cretaceous and Tertiary covering an area of 36350 km².

Modeling Setup

Our initial numerical simulations were done with ECO2N module from the TOUGH2 simulator. ECO2N designed for applications to geologic sequestration of CO₂ in saline aquifers. It includes a comprehensive description of the thermodynamics and thermophysics properties of H₂O-NaCl-CO₂ mixtures (Pruess et al., 2005).

The aquifer is assumed as a homogeneous, isotropic, infinite-acting one. The injection rate is constant at 50 kg/s for a time period of 100 days. Parameters and schematic map are shown below.

Results of Base Case

We use the average value of salinity 0.2 in the base case modeling. The gas saturation, solid saturation as function of the similarity variable are shown below from Figure 3 and Figure 4.

Pruess and Spycher (2007), have shown that the numerical results for the reference case follows a similarity solution. The solution remains invariant when plotted versus the similarity variable R²t, where R is a selected radial distance while t is time. In this paper, we also use it to plot the results to check the accuracy of the numerical simulations.

There are two sharp move fronts shown from Figure 3, that is, the gas saturation front at ζ = R²t > 6.6×10²m²/s and the dry-out front at ζ = R²t < 6.6×10²m²/s. According to the two moving fronts, the displacement process could be divided into three regions. In the region ξ ≤ ξP, the gas saturation can reach 0.9469 while all the liquid phase has been removed. The saturation is occupied by the precipitated salt. The dissolution front, ξ > ξP, is in an intermediate region. The supercritical carbon dioxide and the saline water coexist there. When ξ > ξP, in this region, CO₂ hasn’t yet reacted. The solid saturation should be constant throughout. This remarkable feature can be proved directly from the similarity property (Pruess, 2009). The simulation results show variable solid salt saturation in the dry-out zone, which could be the result of numerical instability problems (Zeiliodi et al., 2009). From Figure 4, we can get the value of solid precipitation 0.05312.

Impact of Salinity on Solid Precipitation

Salinity varies greatly in Jianghan Basin. Three sensitivity tests were conducted by changing the salinity from the base-case of 20 wt% to 10 wt%, 15 wt% and 25 wt%. These salinities were selected by taking account of the variable range covered by the lowest range of salinity and the highest concentration of salinity. The effect of changes in salinity on solid precipitation versus the similarity variable would be discussed hereafter.

Figure 5 clearly delineates that as the salinity increases, the solid precipitation increases. The increasing multiple of solid precipitation is slightly bigger than those of salinity. It’s also revealed that reducing salinity by a factor 2 reduces solid saturation overproportionately by a factor of 2.23 by Pruess (2009). It can be concluded that solid precipitation depends strongly on aqueous phase salinity. With the increase of salinity, the brine viscosity increases. The increase in brine viscosity means the decreasing mobility of the brine in the zone of two-phase flow reduces the displaced brine by CO₂ gas, and increases the evaporated brine. Thus for higher-salinity brine, the solid saturation of the porous medium in the completed dry-out zone has a higher ratio than that for the lower-salinity brine. However, we should note that the increasing salinity reduces the brine vapor pressure (i.e. the water dissolution in gas phase), which is not favorable to the increase in brine salinity during the displacement process.

For the several cases compared to base-case, the dry-out areas in all four cases occur at similar areas on the x-ζ (ξ²t/R²) with occurring in an almost similar pattern as base-case. Solid saturation is the volume fraction of precipitated salt in the original pore space (Garica, 2003; Pruess, 2005). The fraction of the original pore porosity that retards after salt precipitation is what is available for fluid flow (referred to as active flow porosity (Garica, 2003). Hence greater salinity means lesser active flow porosity which in term reduces the permeability of the medium as discussed by Verma and Pruess (1988). Greater salt precipitation may also reduce porosity and impair permeability of the reservoir. The reservoir which could lead to reduction in injectivity which may affect storage operations if injection times.

We have got the values of solid saturation from the modeling results shown in Figures. In addition, the theoretical precipitation of all the dissolved salt could be calculated (Pruess, 2009).

Conclusions

For 1-D radial flow under the similarity property constraints mentioned above, the simulations have provided the following results:

The three different zones ξP < R²t < ξ2.5 P is the zone which contains dry-out of aqueous phase has occurred, the liquid phase has been removed by dissolution into the flowing CO₂, the gas saturation in this region is slightly less than 1. The dry-out zone is followed by an intermediate zone ξ2.5P < R²t < ξm. From the obtained results it was shown that the precipitant occurs only behind a sharp halite front.

The numerical simulation results indicate that solid saturation (fraction of pore space filled by precipitate) in the dry-out region is constant.

As the salinity increases, the solid precipitation increases. The increasing multiple of solid precipitation is slightly bigger than those of salinity.

Two-dimensional simulations of CO₂ injection results showed the following results: Effects of gravity override on gas saturation distributions are strong and solid precipitation distributions are similar. With higher salinity, the value of solid precipitation can reach higher.

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