Numerical Modeling of Reactive Chemical Species Transport in Reservoir Fluids

E.ON Energy Research Center

ACS I Automation of Complex Power Systems

EBC I Energy Efficient Buildings and Indoor Climate

Chemical Model in the Reactive Flow

In the research of reactive flow in hot aquifers, chemical reactions between reservoir rock and fluids are important because dissolution and precipitation of minerals can influence the properties of the reservoir such as porosity and permeability of rocks. The chemical model (Kühn & Pape, 2003) in the numerical flow and heat transport simulator SHEMAT (Clauser, 2003) can calculate the concentration of species and the amount of dissolution and precipitation. The coupling between flow and chemical reaction can be realized through a fractal relation between porosity and permeability. Here, we show a case study, the influence of injected of injected cold water on the mineral composition of a sandstone aquifer containing anhydrite.

Model Description and Assumptions

The model layout is according to Kühn & Schneider (2003) with a study area of 51 m × 51 m and a layer thickness of 30 m at initial temperature of 100 °C. Water is injected in a well in the center (Fig.1) with a temperature of 20 °C and a passive chemical tracer added. The area is discretized with a grid of the size of 1 m long and 1 m wide. The entire simulation time is 4 days for the case of anhydrite. The tables 1 to 6 show time parameters, fluid flow properties, thermal rock properties, transport properties, reaction properties, as well as shows boundary conditions.

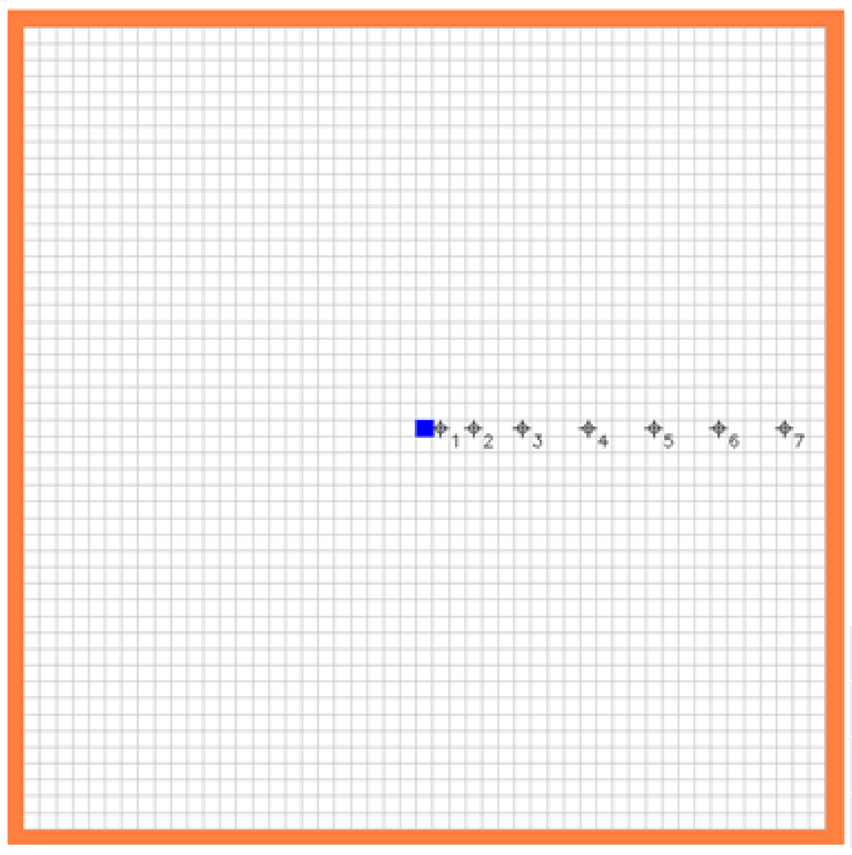

Fig.1: Model domain of 51*51m, injection well in the central part, 1-7: monitoring points.

Table1: Time parameters

Period	Length(day)	Number of time steps	Time step size[s]	Storage frequency
1	4	250	1382.4	3

Table2: Fluid flow properties

Property	Unit	Value
Initial hydraulic heads	[m]	1500
Initial porosity	[-]	0.15
Initial permeability	[m^{-2}]	5.0×10^{-13}
Rock compressibility	[Pa^{-1}]	1.0×10^{-08}

Table3: Thermal rock properties

Property	Unit	Value
Specific heat capacity	[JK^{-1}]	0.7
Thermal conductivity	[$Wm^{-1}K^{-1}$]	2.0
Temperature	[ºC]	100

Table4: Transport properties

Property	Unit	Value
Longitudinal dispersivity	[m]	0.5
Transversal dispersivity	[m]	0.5
Molecular diffusion coefficient	[$10^{-8}m^2s^{-1}$]	0.5

Table5: Reaction properties

Property	Unit	Value
Initial Fluid Composition		
pH	[-]	7.0
Sodium (Na)	[$mmol\ L^{-1}$]	1700.0
Chloride(Cl)	[$mmol\ L^{-1}$]	1700.0
Anhydrite	[$mol\ m^{-3}$]	1000.0
Anhydrite Saturation Index	[-]	0.0
Anhydrite - Molar Volume	[$m^3\ mol^{-1}$]	4.6×10^{-5}
Fractal Exponent	[-]	4.85

Table6: Boundary conditions

Process	Settings
Flow Wells	-1 (constant hydraulic head) 0.0139 m^3s^{-1} injection
Heat Wells	-1 (constant temperature) 20ºC (injection temperature)
Transport Wells	-1 (constant concentration) Tracer 50.0 $mmol\ L^{-1}$
Injected concentrations	pH 7 Na1700.0 $mmol\ L^{-1}$ Cl 1700.0 $mmol\ L^{-1}$

Model Results and Discussion

Anhydrite (Ca SO_4) is dissolved at the injection well, and the dissolved species elements Ca and SO_4 are transported through the aquifer. The anhydrite concentration at monitoring point 1 (at a distance of 1 m from the well) shows the anhydrite is totally dissolved after 3.2 days (Fig.2). The concentration at monitoring point 2 (at a distance of 3 m from the well) shows less solution of anhydrite not exceeding 10% of the total concentration (which was 1000 mmol/L). The temperature at monitoring point 1 converges from 100ºC to 20ºC faster than the one of point 2 because of the distance from the injection well (Fig.3). Fig.4 shows the distribution of anhydrite around the well after 4 days of cold water injection.

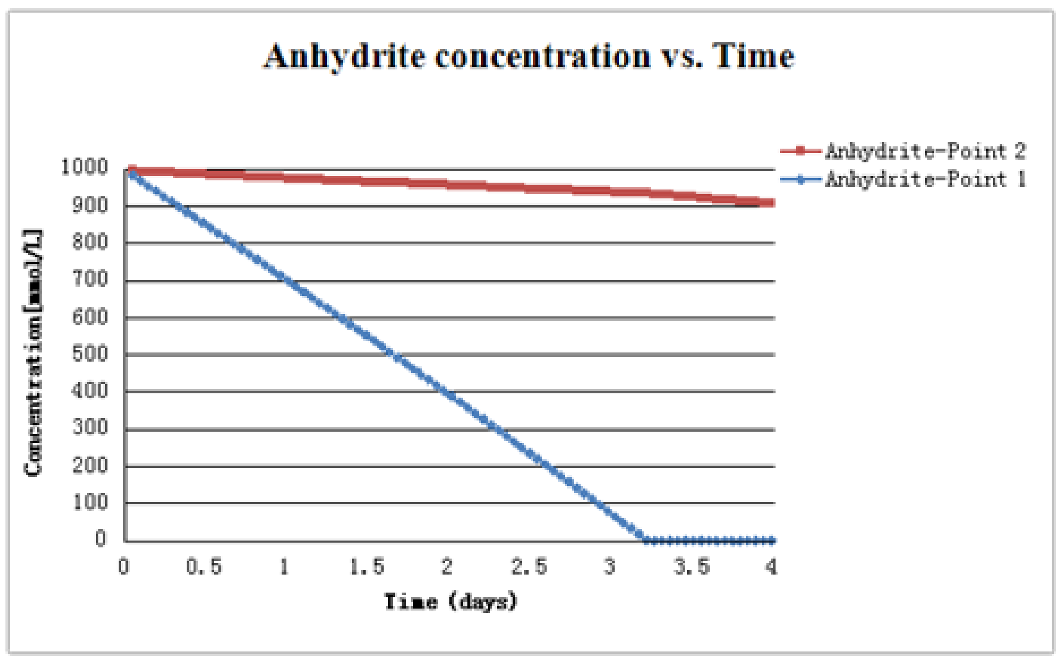

Fig.2: Anhydrite concentrations as a function of time at observation point 1 and 2

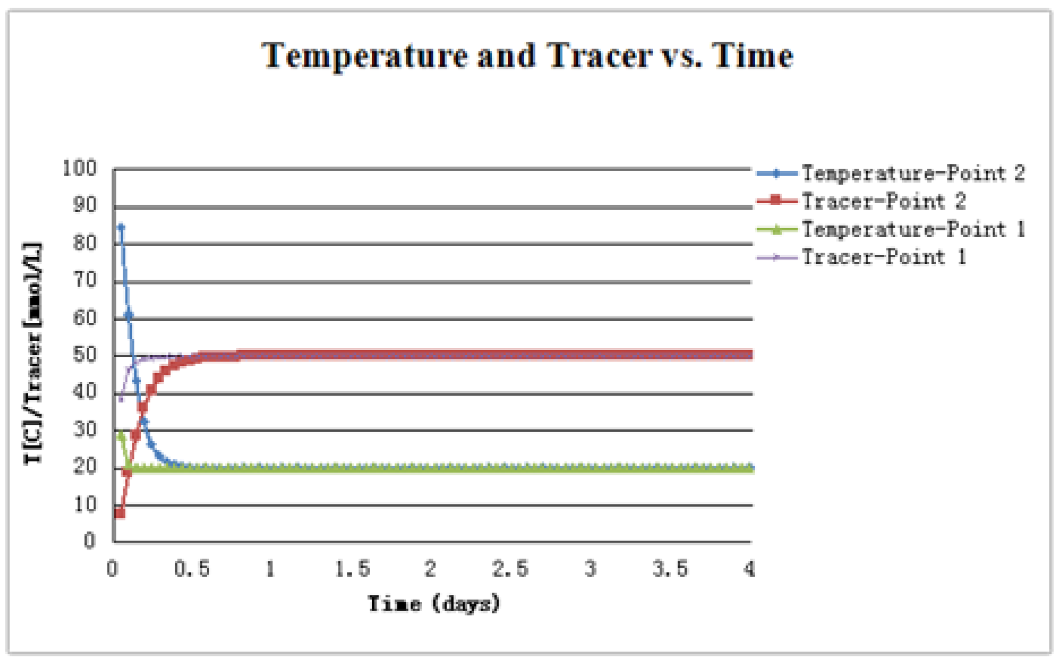

Fig.3: Temperature and tracer as a function of time at observation point 1 and 2

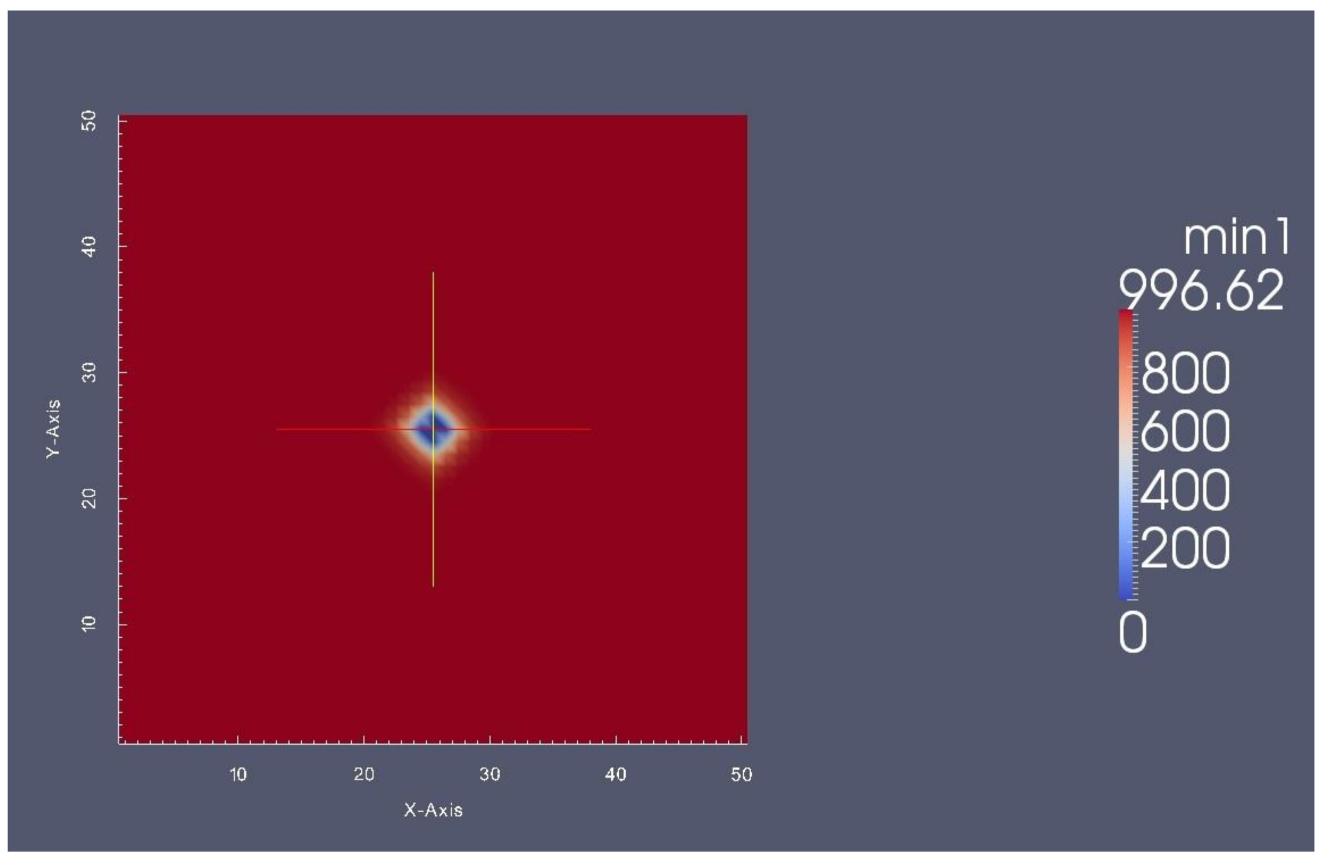

Fig.4: Anhydrite distribution after 4 days. The amount of anhydrite is reduced to zero in a radius of about 3 m around the well (unit is mmol/L).

Conclusion

In this study, the temperature and chemical reactions of anhydrite in a reservoir is modeled as a function of fluid injection. Anhydrite is easier dissolved in cold water than in warm water. Anhydrite is dissolved faster at a near distance than a far distance from the well. The dissolution of anhydrite mineral around the cool well increases the permeability and porosity of the reservoir rock.

SLi@eonerc.rwth-aachen.de
GMarquart@eonerc.rwth-aachen.de

Poster Download

www.eonerc.rwth-aachen.de

RWTH AACHEN UNIVERSITY