Numerical modelling of oilfield chemicals' interaction with porous medium

ELIZABETH OLIVE WUYEP, Gbenga Oluyemi, Kyari Yates, Alfred Akisanya

Robert Gordon University, Aberdeen, United Kingdom

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Outline

- Background
- Objective
- Governing Equations
- Results
- Conclusion

Background and Motivation

- Sand failure a serious challenge in oil and gas industry
- Sand failure occurs when the formation stress exceeds the strength of formation.
- Sand failure is caused by a number of operational factors, one of such is
  - -chemical-rock Interaction
- Chemical-rock interaction is not considered in the current formulation for geomechanical evaluation and sand failure prediction

Objective

- This work investigates interaction of scale inhibitor with carbonate rock numerically for the purpose of accounting for the weakening effect of oilfield chemicals on sand failure prediction.
- Using Chemical reaction Engineering Module in COMSOL Multiphysics

Governing Equations

Equations

- Brinkman
- Rate of reaction
- Mass balance
- Advection-diffusion
- Parameters
- Variables

Physical models

- Fluid flow
- Chemical reaction
- Transport

Brinkman's Equation

$$\rho \frac{\partial u}{\partial t} - \nabla * \eta(\nabla u + (\nabla u)^T) + \left(\frac{\eta}{k} u + \nabla P - F\right) = 0$$

$$\nabla . u = 0$$

Reaction rate Equation

$$r = -\frac{d[A]}{dt} = k[A]$$

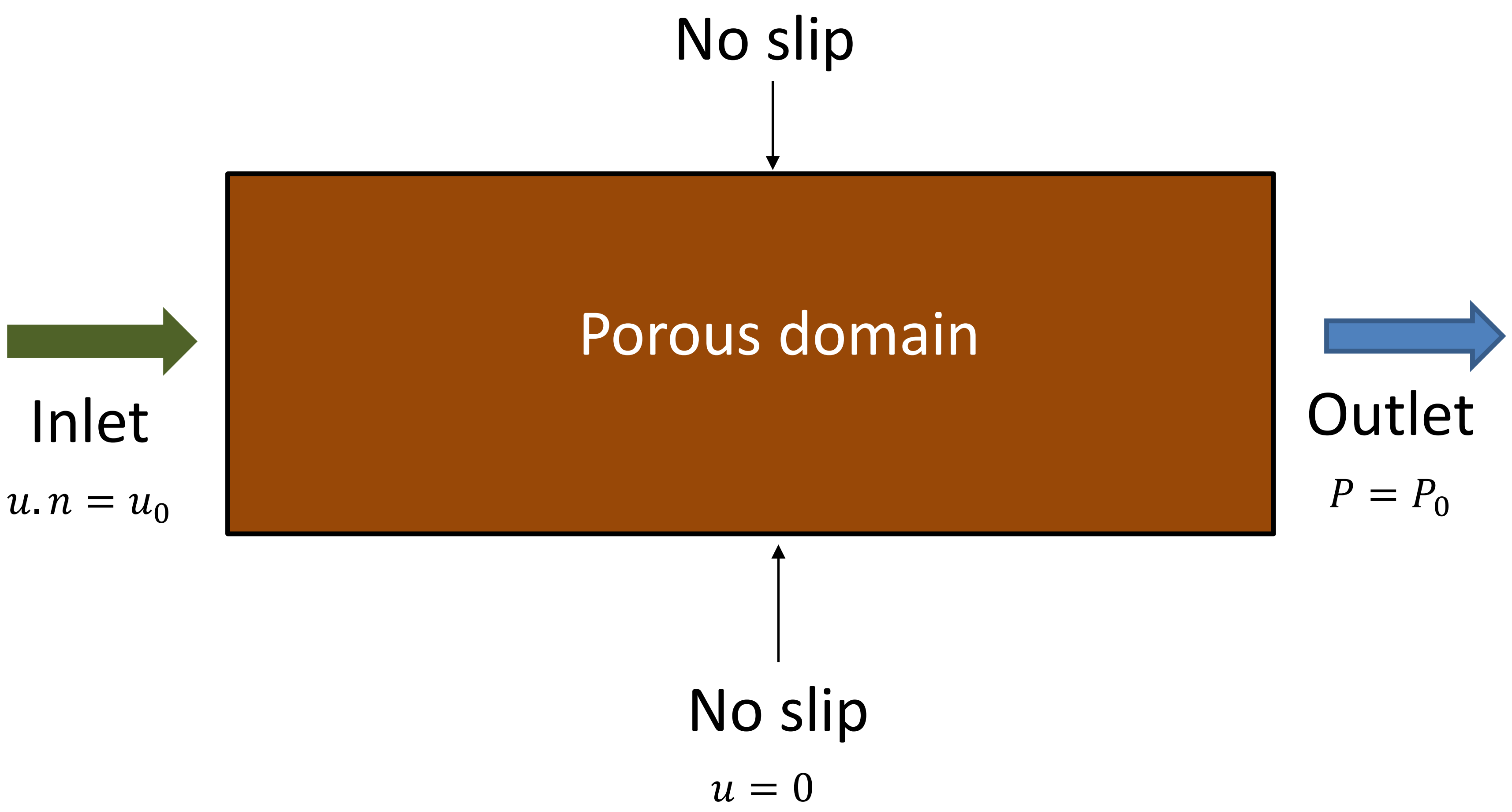
Mass balance

$$CaCO_3 + C_3H_{12}NO_9P_3 \rightarrow C_3H_{10}NO_9P_3 - Ca + H_2CO_3$$

Transport Equation

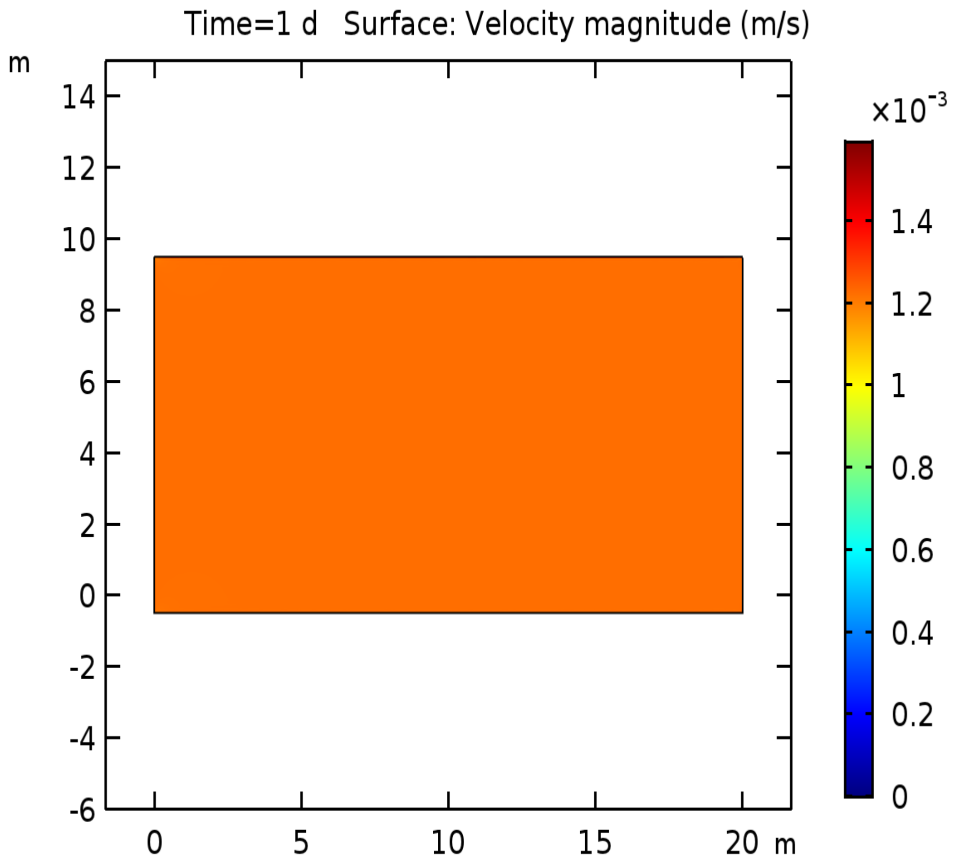
$$\frac{\partial c}{\partial t} = u\nabla C - D\nabla^2 C = 0$$

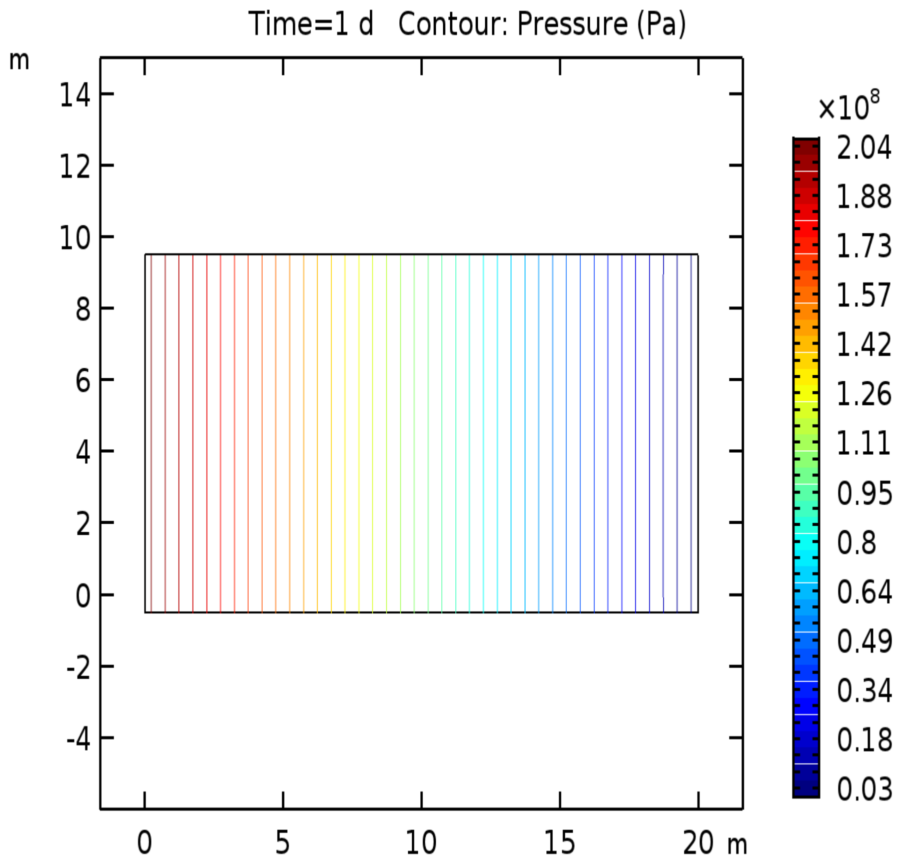
Modelling



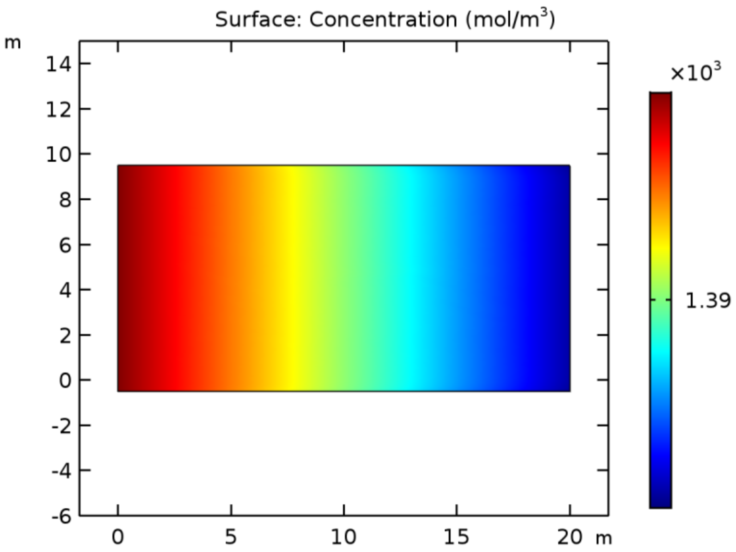
Velocity and pressure distribution

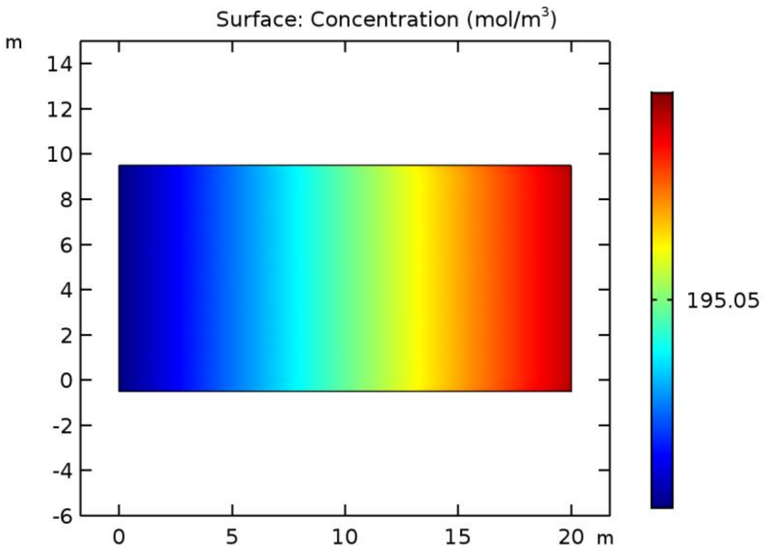
- Brine NaCl
- Uniform velocity
- Uniform pressure
- Steady state

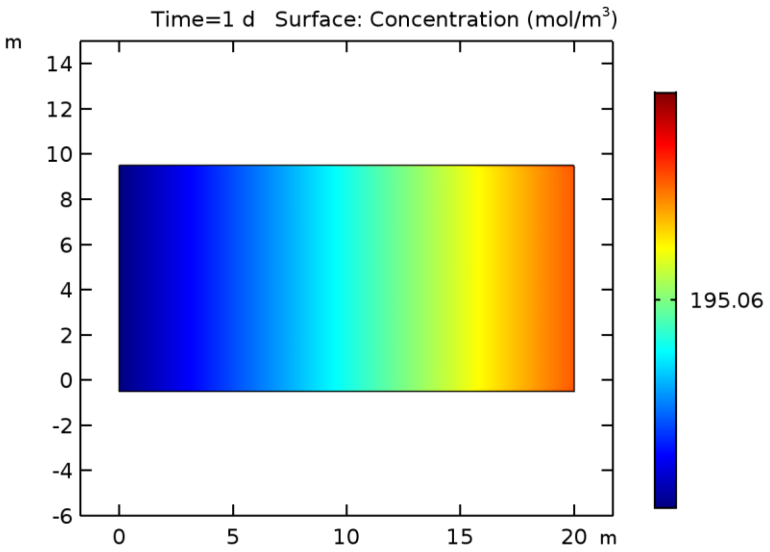




Change in reactant (ATMP) and product (Complex)

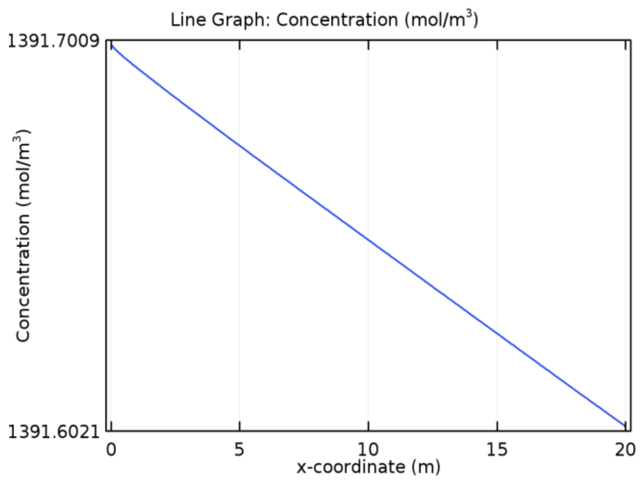


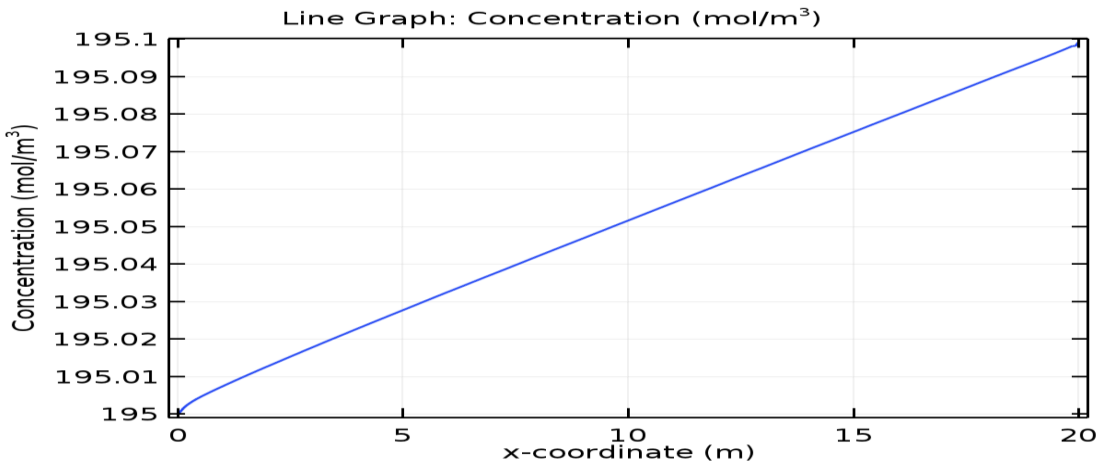




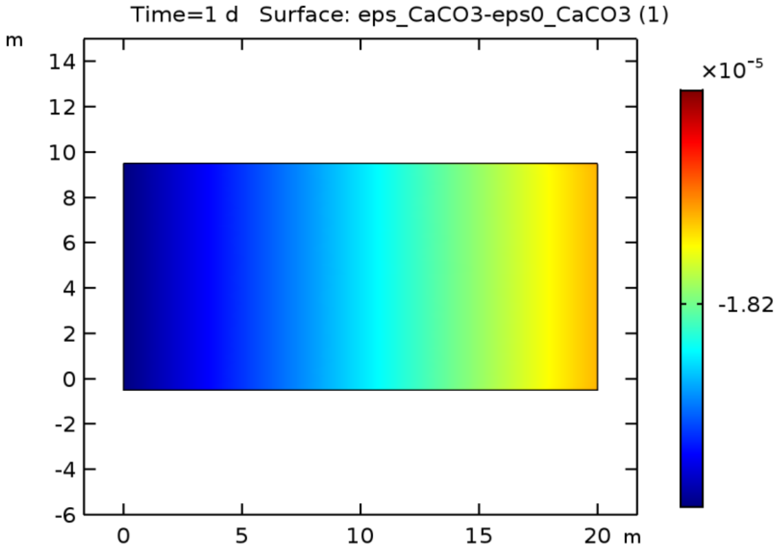
Change in concentration of ATMP at time = 0

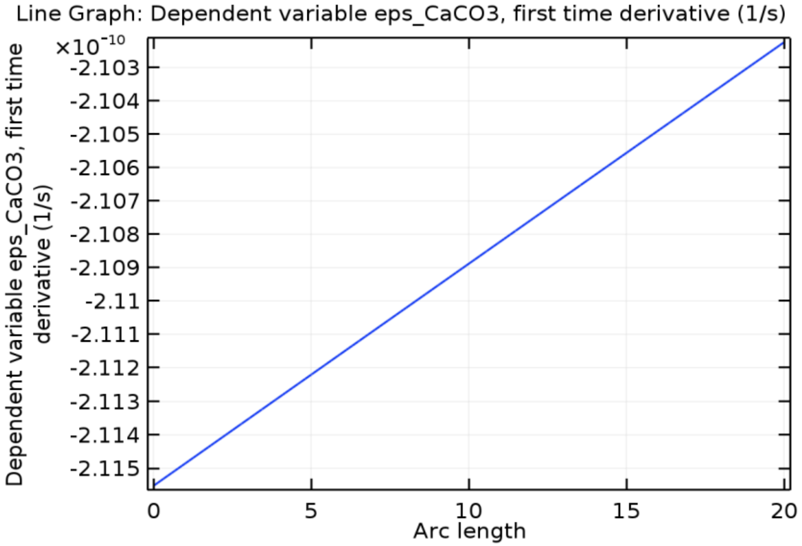
Change in concentration of Ca-ATMP at time = 0 and at time = 1d

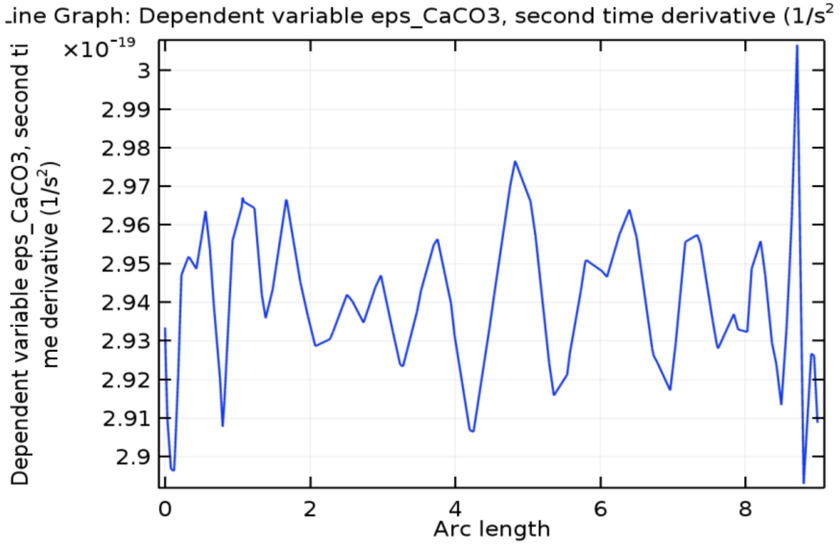


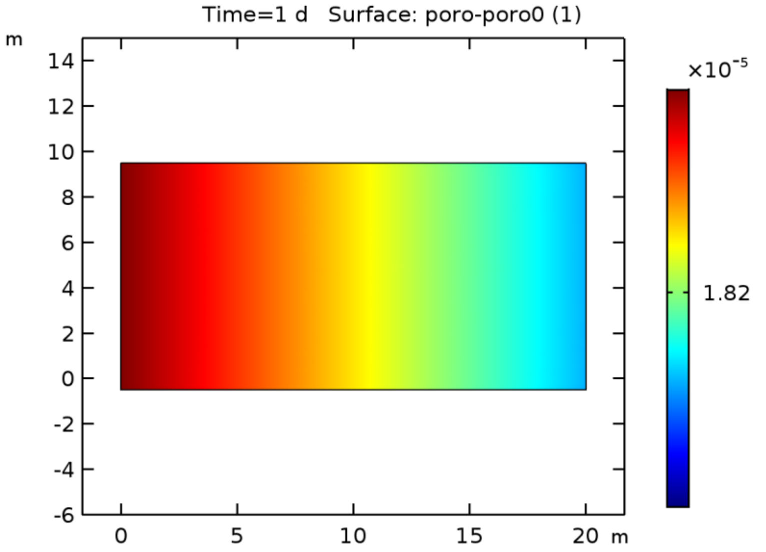


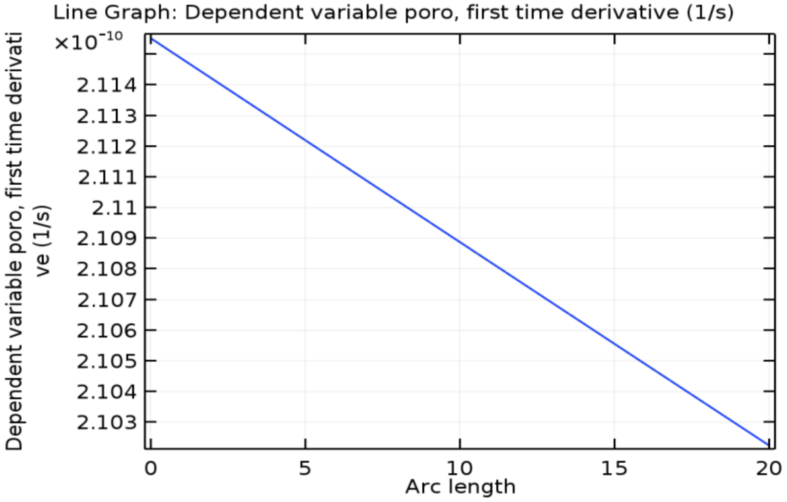
Change in calcite content and porosity

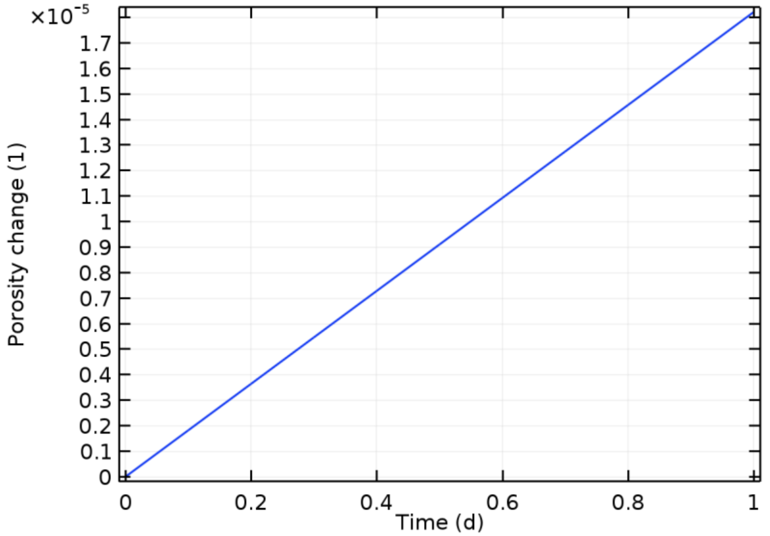












Dissolution/precipitation models

- Rate of relative mineral volume change R_θ
- Rate of dissolution/precipitation R_i

$$\nabla.\boldsymbol{\Gamma}_i + \mathrm{u}.\nabla_{ci} = R_i + S_i \quad [1]$$

$$e_a \frac{\partial^2 u}{\partial t^2} + d_a \frac{\partial u}{\partial t} = S_i \quad [2]$$

$$e_a = 0,\ d_a = 1$$

$$\nabla.(D_i \nabla_{ci}) + \mathrm{u}.\nabla_{ci} = R_i \quad [3]$$

$$u = [\Phi, \theta]^{\tau}$$

$$R_\theta = R_i * \left(\frac{M_i}{\rho_i}\right) \quad [4]$$

Conclusion

- Overall, the fundamental mechanisms involved in the oilfield-formation rock interaction is shown to be dissolution and precipitation reactions
- Dissolution of minerals in the porous medium leads to increase in porosity and grain fabric weakening with a consequence of sand failure
- Precipitation of minerals in the porous medium causes a decrease in porosity and pore clogging with a consequence of formation damage and hydrocarbon production impediment
- Changes in volume fraction of the mineral and porosity are a function of dissolution/precipitation of minerals; and dissolution and precipitation reactions are functions of the type of minerals in the rock.

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THANK YOU