Karlsruhe Institute of Technology

WellboreKit

T-H-C wellbore flow simulator

Institute of Applied Geosciences
Div. of Geothermal Research

WellboreKit: A coupled-dynamic thermohydro-chemical wellbore model for two-phase multicomponent geothermal fluids

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In Short

A new wellbore simulator is established in collaboration between IKET/AGW Karlsruhe Institute of Technology and European Institute for Energy Research (EIFER). The code is developed in Elmer-Python-PHREEQC open-source platform and is able to simulate transient mass flow, pressure, temperature, and equilibrium chemical species concentration profile.
The thermophysical properties of geothermal fluids play an important role for designing the energy conversion systems. Geothermal fluid is a multiphase, multicomponent brine, which can be generalized as the system H_2O – salt (Na–Ca–K–Mg–Cl-HCO_3) – gas (CO_2–N_2–CH_4–H_2S). In this work, we developed an Equation of State (EoS) solver for geothermal fluids (GEOSKIT) using pressure and enthalpy as independent variables. It includes improved gas activity coefficients based on the extension of neutral interactions for the dissolved gases. The solver was developed in the object-oriented scheme to facilitate extension of other salt and gas components. The validity of the solver presented here has been evaluated using the experimental data from literature and online field-measurements applying pressure, temperature, and ionic-strength range of 0.5 – 50 MPa, 32 – 177 °C, and 0 – 8.1 mol/kgw. THC single-phase, chemical equilibrium for reinjection wellbore calculation has been performed to demonstrate the capability of the wellbore flow simulator.

Idea

- Objec-oriented equation of state for geothermal two-phase multicomponent fluids
- Implementation of short-range interaction between dissolved gases to D-S Pitzer derived activity models

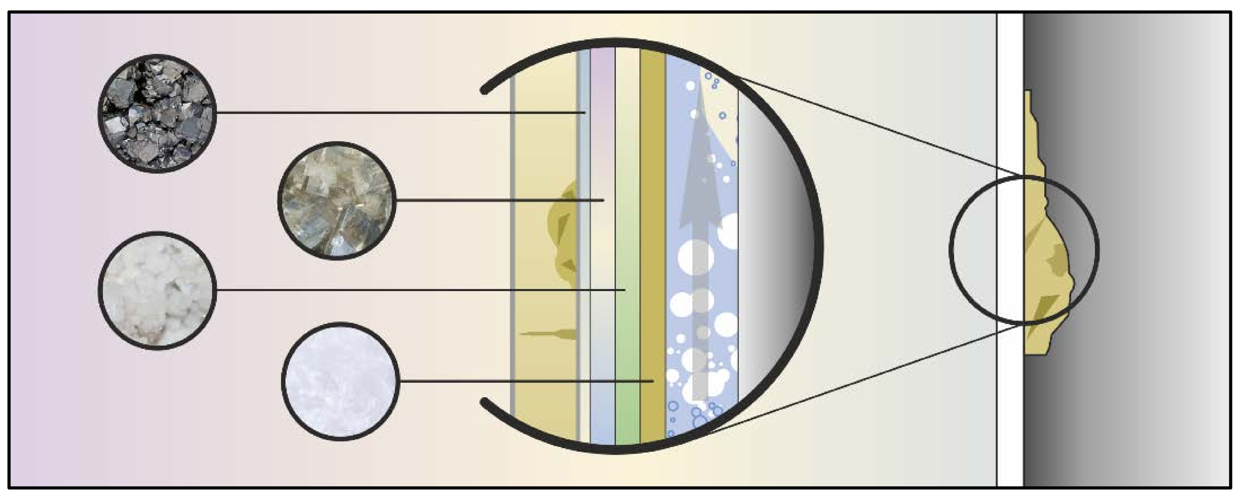


Fig. 1 Mineral scales deposit on wellbore tube comprises of layers depending on its solubility. The equation of state is implemented in wellbore simulator coupled with geochemical solvers to predict scaling phenomena inside the tubes.

WellboreKit: Procedure

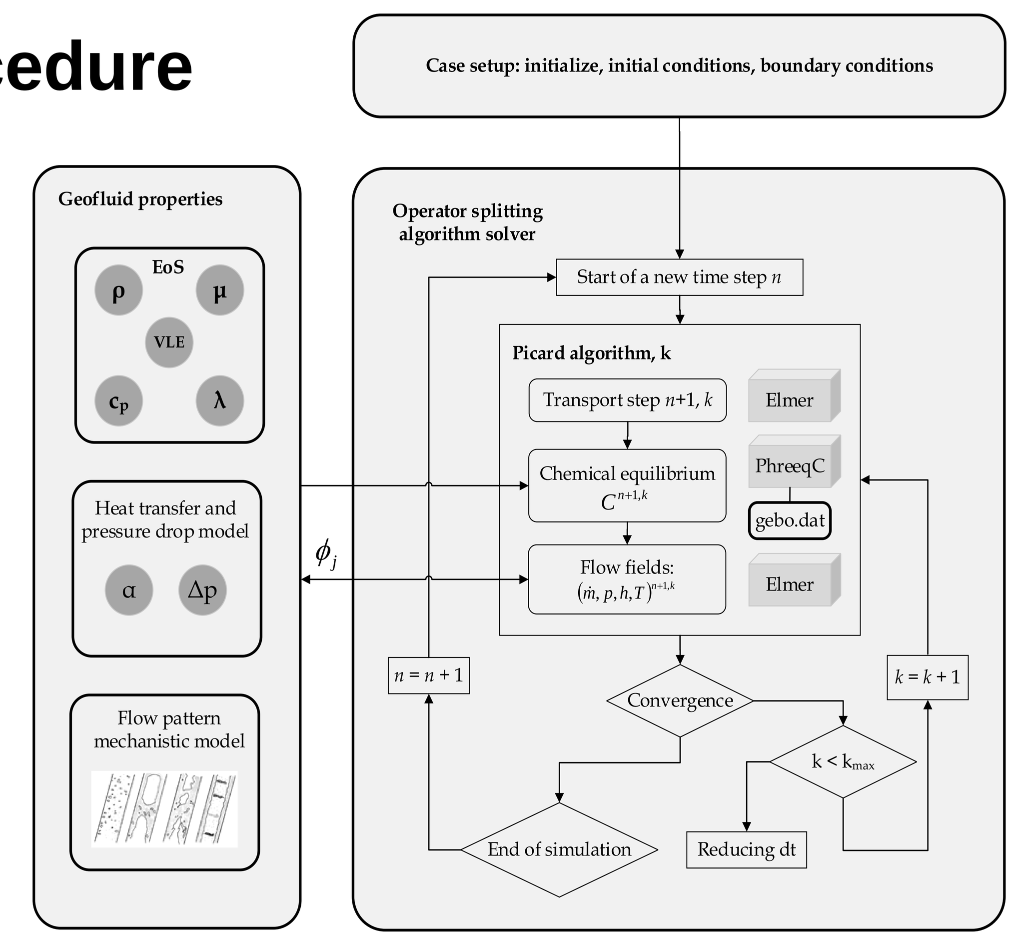


Fig. 2 Unified Modeling Language (UML) class diagram of geothermal fluid equation of state

Validation of the equation of state for geofluids

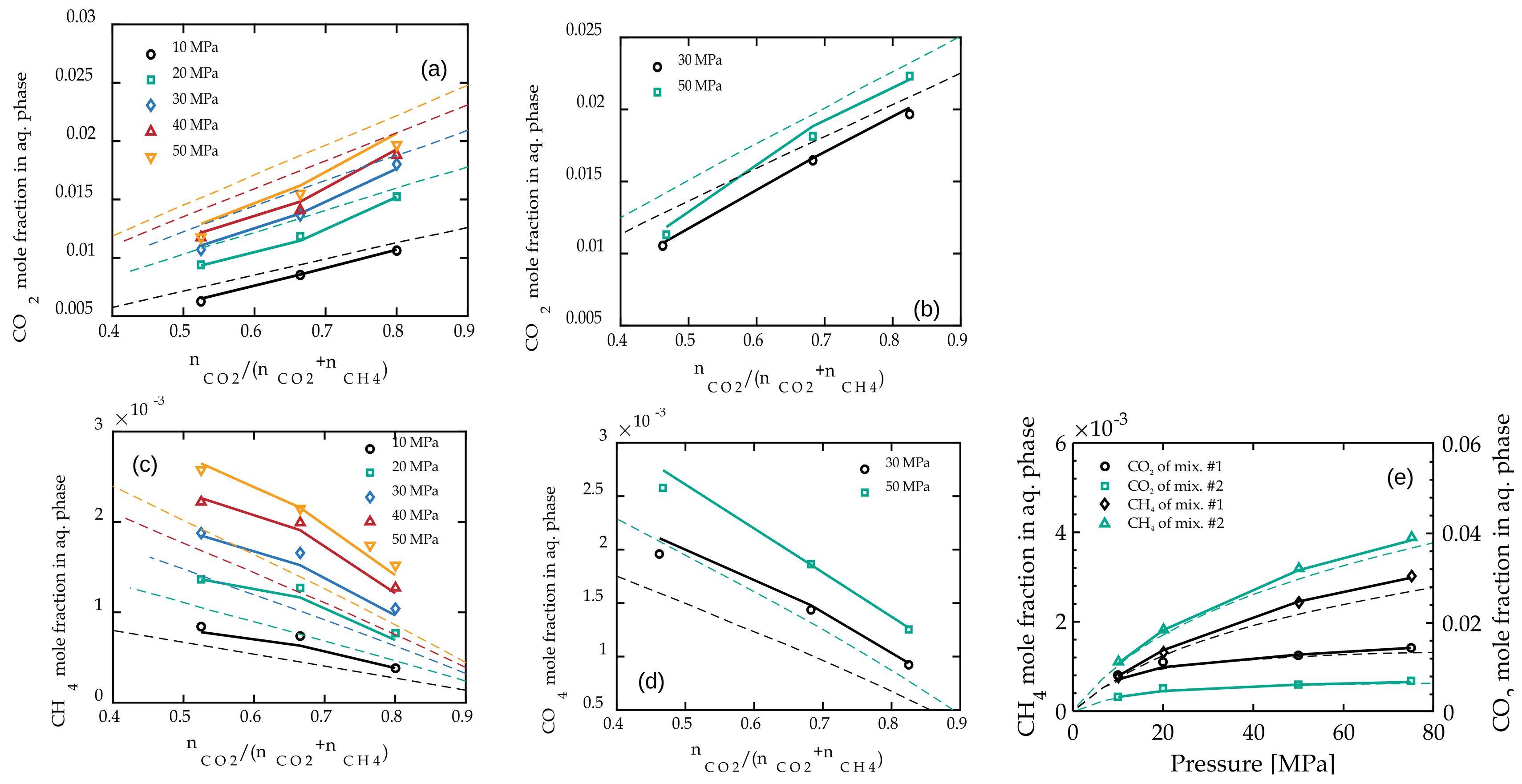
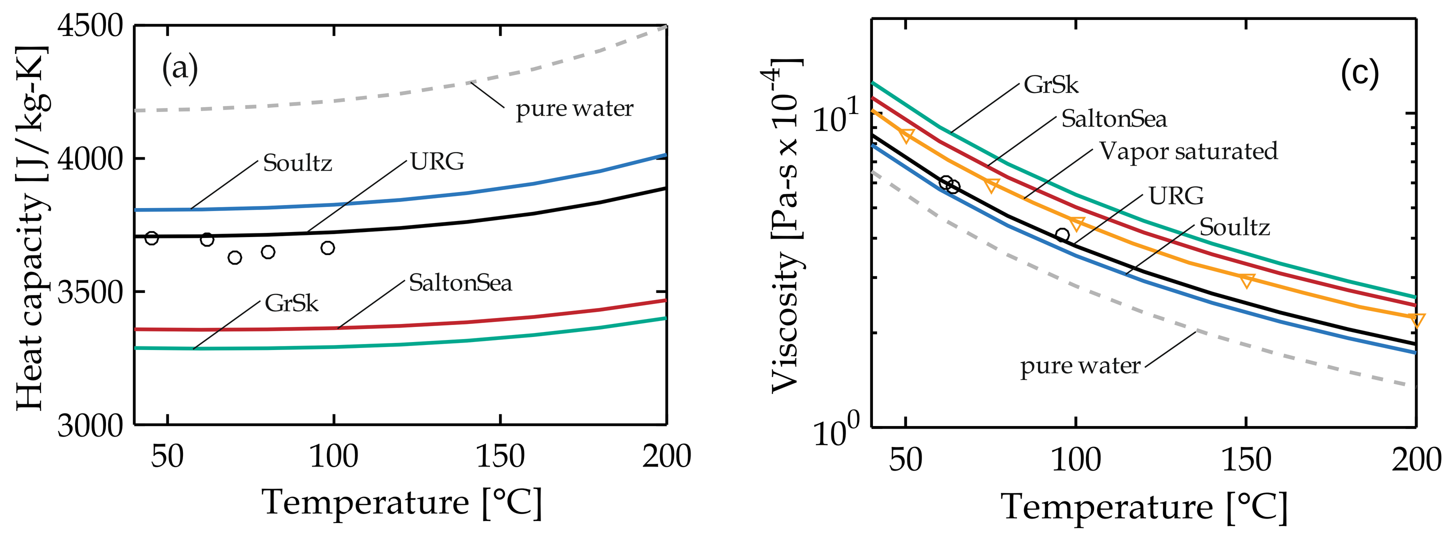


Fig. 3 Aqueous mole fraction of CO_2 and CH_4 varying with CO_2 mole-fraction in dry non-aqueous phase: (a), (b), (c), (d) measured values from (Qin et. al., 2008) are compared with calculated values from GEOSKIT (solid lines) and PHREEQC 3.2 results (dashed lines). The PHREEQC 3.2 results at 103 °C were adapted from Appelo et al (2014); (e) measured values from (Dhima, 2009).



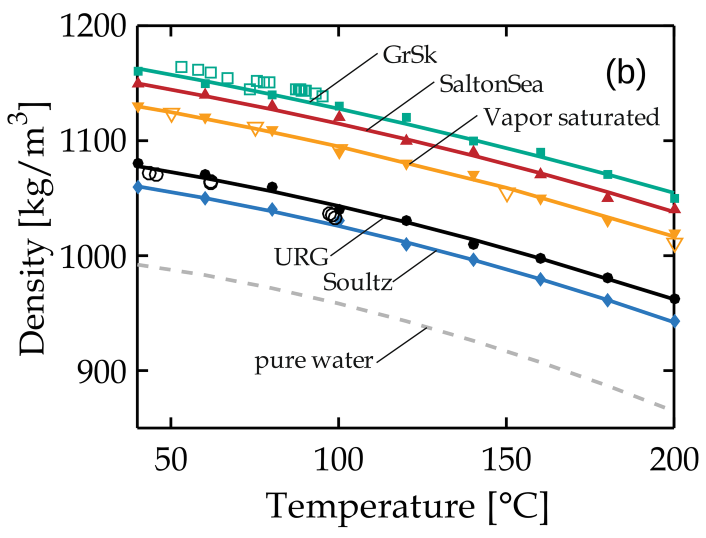


Fig. 5 Aqueous phase properties of real geofluids and vapor-saturated NaCl (3 mol/kgw) solution: Comparison between GEOSKIT (solid lines), PHREEQC 3.2 (filled dots), and measurement data (unfilled circles URG; unfilled squares GrSk; unfilled triangles Vapor Sat.)

Validation of the thermophysical properties solver

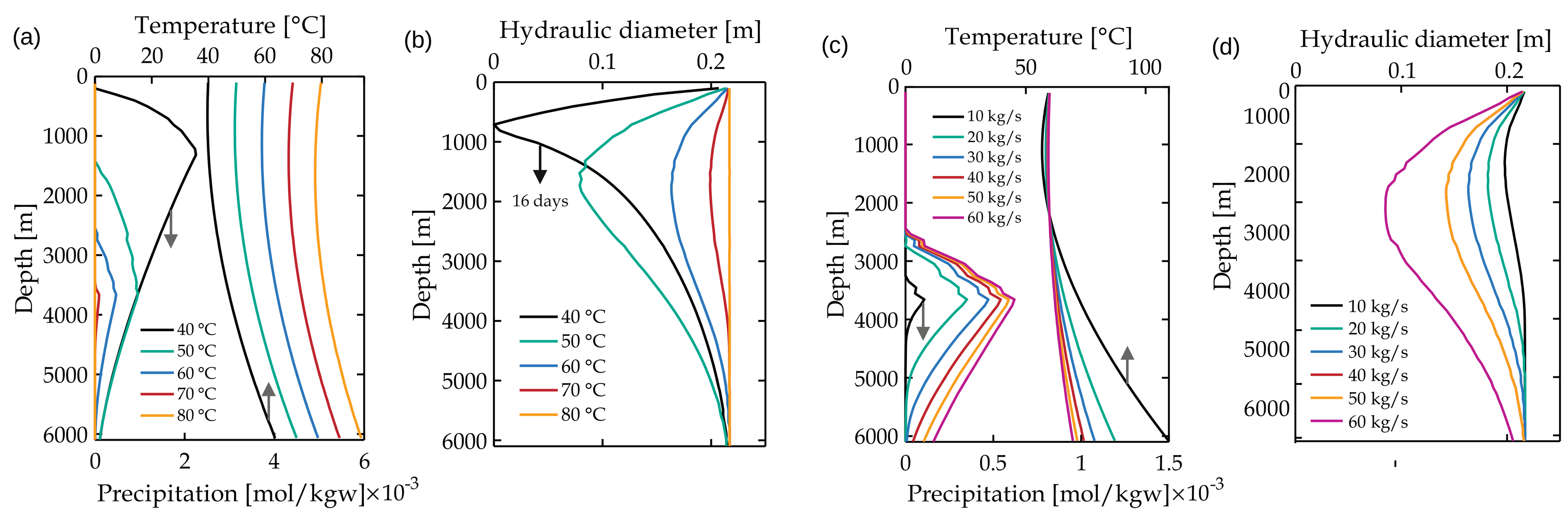


Fig. 4 Sensitivity on reinjection temperature and reinjection rate of saline aqueous barite (Na/Ca/Ba/Cl/SO4 with concentration of 1.105/0.013/1.4E-4/1.408/1.4E-4 mol/kgw, respectively) at 1 moth period: (a, c) Precipitation and temperature profile (b, d) Hydraulic diameter reduction due to barite scaling. All simulations are performed at chemical equilibrium.

Conclusion

The wellbore flow simulator (WellboreKit) has been devised. The built-in equation of state solver can properly reproduce mutual gas solubility and thermophysical properties of geofluid. THC calculation reinjection case has been demonstrated and gave first scaling analysis.

Outlook

- Kinetic chemical reactions of mineral precipitations
- Two-phase THC simulation in production wellbores