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The Hydrodynamic effect on silicate scale growth in microscopic flow inferred from numerical simulation.

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Formation of inorganic sparingly-soluble salts, anhydrite and silica from brine is known as a cause of scale in pipeline systems. Scaling is a key phenomenon to understand fluid-flow system in subsurface or sub-seafloor structure, because the scale growth strongly affects the fluid circulation of subsurface or sub-seafloor hydrothermal systems by chocking any flow channel.

Several works (Takeno et al. 1998; Bolton et al., 1999) simulated the subsurface permeability change by the silica precipitation using the deposition rate law formulated on the basis of the simple kinetics (Rimstidt and Barnes, 1980). However it has been reported that the predicted magnitude of the deposition rate is extremely slower than measured values in the laboratories (Malate and O'Sullivan, 1992; Weir and White, 1996). By the way, a high rate growth of scale is often observed where the flow stagnates, so that the inhomogeneous flow could influence the deposition of the silica scale which is an alternative process of scaling. Nevertheless, relatively little research has been undertaken to investigate hydrodynamic effect on silica scaling. The aim of this work is to investigate the kinetic of adhesion of silica particles on the wall surface based on the hydrodynamic effect using the numerical simulation. Although we focus on the elementary (microscopic) process of the adhesion of silica particles, our ultimately goal is to help us to simulate the macroscopic flow in subsurface or sub-seafloor hydrothermal systems based on the hydrodynamic process by the feedback from this study.

We simulate the adhesion of silica particles using the lattice Boltzmann method (LBM) combined with the smoothed-particle method (SPM) (Nakayama and Yamamoto, 2008). This method uses fixed Eulerian grids for the fluid and represents the particles by certain smooth body forces in the Navier-Stokes equations instead of treating the particles as boundary conditions to the fluid. The LBM is adapted to the flow in the complex geometry due to the simple treatment of the boundary condition. The LBM combined with the SPM is the scheme having low computational cost to deal with many particles in a relatively simple manner. We assume that the particle whose velocity reaches the threshold of the convergence is adhered and is fixed on the wall. We use a two-dimensional parallel plate model in which flow rate and wall roughness are varied and derive the constitutive relation between the deposition rate and flow rate and wall roughness.

A high rate of scale growth is found in areas of low flow rate and it is consistent with the observation at the experiment (Garibaldi, 1980). Therefore, we conclude that the hydrodynamic effect on the growth of silica scale is important to understand the hydrothermal circulation.

Keywords: silica scaling, hydrodynamics, particle adhesion, lattice Boltzmann method, smoothed profile method