Numerical simulations of sub-oceanic hydrothermal system: formation of high temperature fluids by the precipitation of anhydrite

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Introduction

We have performed numerical calculations of sub-oceanic hydrothermal circulations including precipitation of anhydrite (CaSO4). We aim to investigate effects of the anhydrite precipitation on circulation structure, especially to explain the structure of the CaSO4 impermeable layer, which was found by the Suiyo sea mount hydrothermal system.

CaSO4 precipitates when low temperature seawater, which has high CaSO4 concentration, is heated, and when seawater and high temperature hydrothermal fluid,
which has low CaSO4 concentration, are mixed. These features are due to the solubility of CaSO4, which decreases with increasing temperature.

Situation of calculation

We calculate only the area above heat source, at which the large scale upward flow is generated. We assume that the downward flow of the large scale flow, which carries fluids from seafloor to the heat source, is a wall of low temperature seawater. We assume that the permeability structure is two-layered, upper high permeable zone and lower less permeable zone. We also assume that the chemical specie is only CaSO4.

The upper boundary of the calculation is seafloor, whose pressure is hydrostatic at the depth. The lower boundary is above the heat source, whose pressure is also hydrostatic at the depth, but this hydrostatic pressure is due to the wall of low temperature seawater. High temperature fluid, which flows from the lower boundary, has low CaSO4 concentration, and low temperature fluid, which flows from the upper boundary, has high CaSO4 concentration.

Results

The result shows statistically steady state. We found that the circulation structure has three parts, upper cold circulation, lower penetrative flow, and CaSO4 impermeable layer in between. The upper circulation only flows in the upper permeable zone. The fluid has high CaSO4 concentration, which is the same as that of seawater. The lower penetrative flow comes from the lower boundary to seafloor. The fluid has low CaSO4 concentration. The flow is uniform in the lower less permeable zone, but is concentrated in the upper layer because of the upper circulation cells. The two fluids does not mix, because of the impermeable layer.

We also found that the impermeable layer grows through two stages: stable growing and flushing event. When the upper circulation is stable, the layer grows slowly (e.g. 1000 years) at the boundary between the low temperature circulation cells and high temperature flow. This CaSO4 mainly comes from the upper circulation. When the upper circulation is unstable, which occurs once in several hundreds of years, the high temperature flows penetrate the impermeable layer and the upper circulation.