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A numerical examination of quartz precipitations from ascending fluids and resultant increases in fluid pressures

Kenichi Hoshino[1*], Kazuna Fujita[1]

[1]Grad. Sch. Sci., Hirhoshima Univ.

Precipitations of quartz from ascending fluids in fractures and resultant increases in fluid pressures have been numerically simulated to examine the fault-valve model of Sibson et al. (1988) and Sibson (1992). Although a number of detailed analyses have already been made to investigate crack sealing processes around fault zones (e. g., Gratier et al., 2003), essential features of ascending fluids with mineral precipitations resulting in fracture closures have not been analyzed yet. Therefore, two simplified fluid ascending processes have been investigated in the present study: (a) fluids ascend slowly with their temperatures following geothermal gradients and (b) fluids ascend rapidly resulting in isenthalpic or semi-isenthalpic temperature decreases. It can be supposed that the natural fluid ascending systems may take the properties of between (a) and (b).

Decreasing rates of quartz solubility with decreasing temperatures and/or pressures are larger at higher temperatures and pressures. Therefore, when the fluids ascend slowly, the maximum precipitation of quartz may take place at the bottom of the fracture. The precipitation of quartz decreases the fracture width, hence raises the fluid pressure at the bottom. The consequent increase in the fluid pressure gradient may enhance the precipitation, resulting in the most rapid closure of the fracture at the bottom.

When the fluids ascend isenthalpically, boiling conditions may achieve at all depths in the fractures. Therefore, they may boil at the bottom and only steams percolate throughout the fracture, probably resulting in the fracture closure only at the bottom. In cases of semi-isenthalpic ascending with less enthalpy losses, the fluids may also boil at the bottom. Although the fluids may dew at certain depths depending on their degrees of enthalpy loss, the dewed fluids may not precipitate quartz sufficiently for the fracture closure.

On the other hand, the fluids may boil at around the top (probably at several hundred meters below the surface) if the enthalpy losses are adequate. In this case, the largest amount of precipitation may occur at around the top during an early stage. However, an increase in the fluid pressure due to the fracture closure results in a shift of the boiling depth upward. Also, the increase in the fluid pressure decreases the pressure gradient at around the top, resulting in a deceleration of the precipitation. Hence, the amount of the following precipitation at the bottom may exceed those at around the top after a certain duration.

It is quite interesting that the fluids may boil at the bottom or otherwise at around the top depending on their degrees of enthalpy loss. No condition for the fluids to boil at intermediate depths could be found in the present analyses. Those results imply that there may be threshold values of the degrees.

The fluids may not boil when the amounts of enthalpy loss are large, probably resulting in the same properties as the slowly ascending fluids.

The analytical results of the both simplified fluid ascending processes (a) and (b) indicate that the fractures may close mostly at their bottoms.

It should be noted that the above conclusion may be applicable for the fluid ascending systems from any depth. That is, there may be no inevitability for the fracture closure at around the depths of earthquakes.

Keywords: fluid, fracture, quartz, fault, fluid pressure, fault-valve