Numerical Study on Degassing of Magma Chamber in Geothermal System

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It is known that there are geothermal fields where we can find geothermal phenomena such as hot springs, fumaroles, and hydrothermal alteration. 535.25 MWe (in 2003 [4]) of geothermal energy is produced in Japan. Numerical simulation on fluid flow in the geothermal system is often conducted in terms of development or scientific interests about the subsurface thermal structure. Today the target of this simulation is only in strata, though the calculation can deal with transient multiphase flow (hot water and vapor) in 3D space. It is generally presumed that a magma chamber is the ultimate energy source of geothermal system at a depth of a few to several kilometers. The magma chamber can discharge magmatic fluid and supply it into the above hydrothermal system. The conventional numerical simulation technique, however, cannot help dealing with this phenomenon by injecting the fluid from the bottom of the target region at some rate. The modeling for not only fluid flow in the hydrothermal system but also cooling magma chamber as a heat source is required in order to comprehensively view the geothermal system including the relatively shallow hydrothermal system and the deep heat source, and to argue the evolution of the geothermal system since emplacement of the magma chamber in a timescale of tens thousands of years or more.

We refer to two examples about cooling mechanism of the heat source. In Kakkonda geothermal field, northeastern Japan, conductive heat flow from the heat source to the hydrothermal system was confirmed by drilling [3]. In Kuju-iwoyama, southwestern Japan, where intensive fumarolic activity can be found, on the other hand, the ratio of magmatic fluid discharged from the fumarole was estimated with numerical simulation based on heat conservation and analysis of hydrogen and oxygen isotopic ratio [1]. The result showed that 75 % of fumarolic fluid came from the magma chamber. The former example may allow to argue the evolution of the geothermal system regarding the cooling process of the magma chamber as a problem of thermal conduction [2]. It is, however, difficult to accept the phenomena of the latter one as thermal conduction because intensive degassing of the magma chamber must be considered.

We will report our attempt to numerically model the cooling process of magma chamber accompanied by degassing. The governing equations for natural convection of magma, crystallization and degassing are suggested and numerically solved. The exsolution of volatile component is particularly dealt with as a problem of bubble nucleation and growth based on the model by Toramaru [5].

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