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SPH法によるマグマ貫入過程の数値シミュレーション

Computer simulation of magma intrusion processes using an SPH method

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The process of magma intrusion into the country rock consists of fracturing of the rock and following penetration of sheet-like magma into newly formed cracks. This process involves both solid and fluid materials and is accompanied by large displacements of solid-fluid interfaces. Due to these natures of the problem ordinary methods of numerical calculations using spatially fixed lattice or mesh points are difficult to apply to the computer simulation of magma intrusion. The problem can be treated more easily by particle dynamics, particularly an SPH (Smoothed Particle Hydrodynamics) method in which the states and motions of particles are calculated so as to keep a formally good correspondence with continuum mechanics.

In the present paper some basic problems we may encounter in simulating magma intrusion processes in the SPH method are carefully examined using numerical experiments with a simple system of particles. In this system fluid particles in a pool are poured into an overlying pool occupied by another group of fluid or solid particles with a different physical property. Both of the upper and lower pools are of rectangular or parallelepiped shapes with bottom, side and interface walls constructed by boundary particles. In the operation of a numerical experiment the boundary particles at the bottom are moved upward at a prescribed constant speed to raise pressures of intruding fluid particles and those forming the side walls are moved laterally to control the stress conditions of intruded particles.

This system of numerical experiments is readily applied to the fluid intrusion into a fluid matrix, which requires only a standard treatment of viscous fluid in the SPH method. The experiment can simulate some features of the intrusion. On the other hand the experiment reveals presence of significant fluctuations in the change of velocity and stress components of individual particles. Such fluctuations associated with particle motions are considered to be a basic nature of particle dynamics but they severely prevent us from applying a fracture condition to solid particles because the condition is usually written in terms of certain stress components compared with the solid strength. It is noted in this context that fluctuations of particle states can be substantially confined by an artificial viscosity that is introduced in the equation of motion for particles.

The fluid intrusion into a solid matrix that follows fractures of solid particles can be successfully simulated with a suitable application of the artificial viscosity. In our numerical experiment Mohr-Coulomb criterion is employed for the fracture condition and the solid particles that have been fractured are treated to transform into fluid particles that may suitably represent fractured states. Consistently with a familiar idea the experiment shows that pressures of intruding fluid particles are significantly enhanced while horizontal extension concentrates in the solid particles near the intrusion front. The experiment further predicts that an extensional stress environment favors fluid intrusion but an intrusion is realizable even under a compressive stress condition if pressures of fluid particles are raised enough.

キーワード:マグマの輸送,マグマの貫入,破壊,粒子法, SPH法,数値シミュレーション

Keywords: magma transport, magma intrusion, fracture, particle dynamics, SPH method, computer simulation