V033-P012 Time: May 29　17:00-18:30

A numerical study of porous flows by the lattice Boltzmann Method

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1. Introduction

Flows through porous media play a significant role in many volcanological situations. For example, the eruption type may be largely affected by degassing process due to porous flow from volcanic vent. The efficiency degassing thorough porous media around volcanic vent is controlled by bubble connectivity of pumice and scoria, crack size, grain sizes of surrounding rocks. Permeability is a key parameter in order to evaluate such porous media. Generally speaking, the permeability depends on many factors such as porosity, typical length scale of pore, grain size distribution, anisotropy and tortuosity of pore connections. Therefore, it is difficult to analytically calculate the permeability for porous media with complex structures. The purpose of this study is to develop a numerical method that determines the relationship between the permeability and the statistic properties of the structure in porous media.

2. Methods

In this study, we use 2-dimentional lattice Boltzmann method for incompressible fluid. The lattice Boltzmann method is a very efficient numerical tool to investigate flows in highly complex geometries, such as porous media. We numerically determine physical quantities of steady flows through various porous media under boundary conditions of constant pressure difference. The permeability can be determined by the ratio between pressure drop and fluid flux on the basis of Darcy's law.

3. Results and Discussion

In order to test the accuracy of the present numerical method, we calculated 2 dimensional Quette flow, Poiseuiile flow and the cavity flow. The numerical results by the present method agree well with analytical solutions for these flows and/or the results in previous studies using other numerical methods (e.g. finite different methods).

We determined the permeability of analogous porous media with complex structure (e.g. the Sierpinski-type carpet). The results show that for a given geometry calculated permeability gives a consistent value when more than 3 meshes are set for the narrowest channel of the porous media. It is suggested that the present method is accurate enough to predict the permeability for porous media with complex structure when more than 3 meshes are set for the narrowest channel.

Because of limited power of computer, the present method is applicable only when the ratio of the largest length scale of pore to the smallest one is less than 100 at present. For example, we can determine the permeability of typical sandstones with grain size ranging from 2 to 1/16 mm. However, it is difficult to determine the effective permeability if such sandstone coexist with cracks with larger pore space. In order to calculate the permeability for those porous media, we must develop further numerical technique such as parallel computing.