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Numerical study of pressurization process of an evolving magma reservoir: Comparison with periodicity of volcanic eruptions

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INTRODUCTION

Eruptive activities of volcanoes often have periodicity (Simkin and Siebert, 1994). It is, on the other hand, suggested that the pressurization process of a magma reservoir because of crystallization of magma and accompanying volatile exsolution causes an eruption (Tait et al., 1989; etc.). This study investigated the characteristic time scale of this process and compared it with time interval between real eruptions by constructing a numerical model.

NUMERICAL MODEL

Mathematical models of this pressurization process have been already suggested by previous studies (Blake, 1984; Tait et al., 1989; Woods and Pyle, 1997; etc.). The new point of the numerical model of this study is to strictly consider the change with time and spacial coordinates by numerically solving partial differential equations.

The target region of the numerical model is a silicic magma reservoir and surrounding crust. In the magma reservoir thermal convection of magma is analyzed. Magma consists of melt, crystals and exsolved volatiles, but it is regarded as homogeneous Newtonian fluid with mean physical properties for simplicity. In the crust, on the other hand, thermal conduction is only considered. The pressure change in the magma reservoir is expressed, considering crystallization, volatile exsolution, and elastic deformation of the crust. Assuming an appropriate critical pressure, eruption time and erupted volume are estimated.

The initial time is the emplacement of the magma reservoir with uniform liquidus temperature and volatile saturation at the roof. The calculation was done until pressure reaches the critical value.

CALCULATION AND RESULT

The numerical model is governed by nineteen dimensionless parameters. Assuming appropriate values of the other sixteen parameters, this study investigated the governing regime of following three parameters: spacial scale gL^3/k^2 and relative depth P/(dgL) of the magma reservoir, and Prandtl number of the magma Pr, where L is magma reservoir dimension, P lithostatic pressure at the magma reservoir roof, d density (rho in Fig.), k thermal diffusivity (kappa in Fig.), and g gravity acceleration.

Changes in dimensionless eruption time and erupted volume with these parameters were obtained. Using this calculation, eruption time in year and corresponding VEI (Volcanic Explosivity Index) with arbitrary parameter variations were estimated. The result showed that the time interval between real eruptions with VEI=5 shown by Simkin and Siebert (1994) is consistent with the calculated eruption time under the following condition:

gL^3/k^2: less than 1.7×10^{24},
P/(dgL): from 0.5 to 1.5,
Pr: from 3.1×10^6 to 3.1×10^8,
$(gL^3/k^2)^{0.56}(P/(dgL))^{-1}$: less than 2.5×10^{13}.

This suggests that the characteristic time scale of the considered pressurization process has relationship with periodicity of eruptive activities under the above condition.

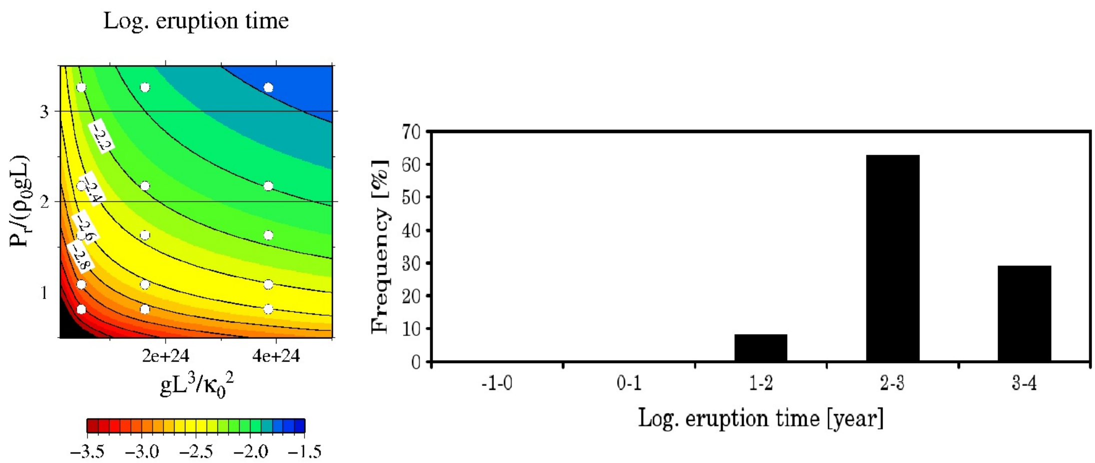

Fig.: Calculated dimensionless eruption time $\kappa_0 t/L^2$ with Pr=3.1×10^8 (left) and estimated eruption time frequency with VEI=5 (right).