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Numerical calculation of convection in a magma chamber and melting of the roof with a one-dimensional parametarized model.

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1. Introduction

Melting of the mafic lower crust is thought to be one of the generation processes of granitoids. The condition for melting of the lower crust by the heat conducted from intruded magma sills has been investigated numerically. Petford and Gallagher(1) suggested that even short cyclic magma intrusions, which causes the most effective melting, cannot produce sufficient melting, while Annen and Sparks(2) performed numerical calculations with plausible parameter ranges of the properties of rocks, and showed that longer cyclic magma intrusions can produce more lower crust melt. Both studies are considering conducting heat transfer only, however, thermal convection may occur in the intruded magma chamber and convective heat transfer may not be negligible. Moreover, the lower crust may be eroded and mixed with the convecting magma chamber, and the amount of the lower crust melt might be decreased. In this study, we construct a numerical model which can treat heat transfer by thermal convection in the magma chamber and erosion of its surroundings, and investigate the influence of thermal convection in the magma chamber and assimilation of melted lower crust on the amount of the mafic lower crust melt.

2. Model

Our numerical model consists of a vertical one-dimensional domain; we assumed that the magma chamber intrudes as a form of sill, and neglected the influence of its side wall. The variables describing states of rocks are temperature and melt fraction. The governing equation is that of heat transport, expressing that enthalpy varies according to the convergence of heat flux. Enthalpy is the sum of internal energy, and latent heat which is proportional to melt fraction. Internal energy of the mantle and the lower crust is the product of their density, specific heat and temperature, respectively. Melt fractions of the rocks in the model vary linearly from their liquidus to the solidus temperatures, respectively. For the given enthalpy, the temperature and the melt fraction can be determined diagnostically. We assumed that convection occurs in the basaltic magma chamber when its melt fraction exceeds 0.5, and enthalpy is distributed uniformly. The convective heat fluxes through the boundaries of the convecting magma chamber are estimated by the four-third power law of the temperature difference at the boundaries(3). Besides the convective region and its boundaries, heat is transported by conduction only. It was assumed that the lower crust and the mantle adjacent to the convective magma chamber are eroded and mixed into the magma chamber when their melt fractions exceed 0.5, and enthalpy of the expanded magma chamber is redistributed uniformly. For simplicity, we assumed that the properties of the assimilated melt become the same as those of the basaltic magma.

3. Experimental setting and Results

The computational domain is between 30km and 40km depth. The Moho is located at the depth of 35km. The basaltic magma chambers with the 200m thickness are intruded below the Moho 5 times at an interval of 200years. Numerical time integration is performed for 60000 years after the initial intrusion. For comparison, the case with conduction only and the case with convection but without erosion are calculated respectively. The numerical results show that the produced total melt thickness is only 400m when the convection and erosion is considered while it is about 800m in the cases without erosion. The compacted melt thickness is 50m, which is 1/4 of those in the cases without erosion. This decrease of the lower crust melt is caused by the assimilation of the lower crust melt to the convective magma chamber. Our results suggest that the conclusions of previous studies considering only conductive heat transport should be reexamined.

References

1) Petford, N., Gallagher, K., EPSL, 193, (2001), 483-499

2) Annen, C., Sparks, R. S. J., EPSL, 203, (2002), 937-955

3) Turner, J. S., Cambridge Univ. Press, (1973), 368pp.