Long-term input rate of mafic magma inferred from a long-term heat balance model of silicic magma reservoir

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A model, which represents a formation dynamics of eruptible silicic magma reservoir made from partially melted crystal rich mush in the upper crust generated by inputs of mafic magmas supplied from mafic magma reservoirs accumulated in the lower crust, is beeing generalized (e.g. Sparks et al., 2019). According to this model, it is likely that an eruption of felsic magma is caused by inputs of mafic magmas. Knowing the input rate of mafic magma is, therefore, important not only for an understanding the magma dynamics but also for a long-term evaluation of eruption possibility. Koyaguchi and Kaneko (2000) proposed the concept, and discussed the development process of the silicic maga subdivided into two stages: the stage of rapid rise in the temperature, partial melting, disturbance, rapid cooling of the felsic magma due to the input of mafic magma (Convection & Melting (C & M) mode), and the subsequent conductive cooling stage (Conductive Cooling (CC) mode). In this paper, I would like to suggest that we may be able to estimate a long-term mafic magma input rate using an improved model of long-term heat balance of the CC stage if a magma reservoir size is obtained underneath the volcano with known eruption rate during the past thousands of years observed by the geological study.

The basic formulas of the model are following equations:
$\Delta Q = I\rho\{cT_{\mathrm{b}} + L(1 - \phi_{\mathrm{crit}})\} - E\rho cT_{\mathrm{eft}}$, (1)
$Q_{\mathrm{loss}} = 2\pi\{a + b(\tanh^{-1}e/e)\}k(T_{\mathrm{eft}} - T_{\mathrm{wrt}})$. (2)
Here, ΔQ is the difference between the power of the erupted magma (E: long-term eruption rate; km^3/kyr) and that of the input magma (I: long term input rate; km^3/kyr), and Q_{loss} is the power dissipation of the oblate spheroid shape magma reservoir. a is a major axis of the spheroid, b is its minor axis, and e is the eccentricity. ρ is the density of the rock, c is the specific heat of the rock, L is the latent heat of fusion, k is the thermal conductivity, ϕ_{crit} is the melt fraction of the eruptable magma, T_{b} is the temperature of the mafic magma, T_{eft} is the effective temperature of eruptible magma, T_{wrt} is the crustal temperature around the magma reservoir. Furthermore, assuming that ΔQ can not be completely consumed by Q_{loss}, the residual power Q_{ex} is: $Q_{\mathrm{ex}} = \Delta Q - Q_{\mathrm{loss}}$ (3) and that of the volume increase rate (R_{ex}; km^3/kyr) is: $R_{\mathrm{ex}} = Q_{\mathrm{ex}} / \rho cT_{\mathrm{eft}}$ (4).

Next, I conducted to calculate the supply rate of mafic magma by assuming concrete cases using this model. For example, if a = 3600 m was observed underneath a volcano which was geologically obtained the long-term eruption rate of 0.1 (km^3/kyr), the magma input rate for maintaining the magma reservoir size (Q_{ex} = 0) was calculated to be 0.5 (km^3/kyr), assuming that T_{wrt} = 100 °C, the flatness ratio of the magma reservoir was 0.7 (1-b/a) and other parameters were refferred to Koyaguchi and Kaneko (2000). This model, however, has a large dependency on T_{wrt}. For example, if the same injection and input rate were assumed as above instance, it balanced at a = ˜ 20 km when T_{wrt} = 500 °C. With this model, although there is a large temperature dependence of the surrounding crust, it could be shown that the long-term input rate of mafic magma during the past thousands of years can be estimated by knowing the present size of the magma reservoir underneath the volcano with the known eruption rate.

Keywords: heat balance model, long-term eruption rate , long-term magma input rate, size of magma reservoir

