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Effects of relationship between temperature and melt fraction of crustal rock on magma generation by crustal melting

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Crustal melting by injection of hot magmas is an important process for magma genesis in continental crust. Most magmas in arc magmatism in continental crust like Japan are probably produced by crustal melting. An aim of this study is to understand constraints of composition, amount, and generation timescale of magmas produced by crustal melting due to hot magma injections. So far, we investigated amounts of mafic and silicic magmas and timescale of magma production by crustal melting using a one-dimensional physical model. In the model, it is assumed that crustal rocks have almost linear relationship between temperature and melt fraction (the relationship is referred to be as melt fraction as function of temperature, F(T)). On the other hand, F(T) is not linear in general cases. For example, F(T) of hydrous granite steeply increases without temperature increase near its solidus, while F(T) of hydrous basalt less increases with temperature near its solidus. Thus, F(T) affects amount of magmas generated by crustal melting. We report effects of F(T) on magma generation by crustal melting in this presentation.

The model of crustal melting by Koyaguchi and Kaneko (2000) is followed. When a crust is melted by a hot magma injected into a crust, large heat flux from the convecting injected magma rapidly melts the overlying crust up to the degree of partial melting large enough to convect (~100 yr timescale). After that, the injected magma and convecting region of partially-molten crust decrease in temperature and melt fraction, and hence cease to convect for melt fraction to decrease down to the critical melt fraction where the mixture of solid and liquid cannot convect. At this stage, heat transfer becomes only conductive and slow (>10,000 yr). When a new injection of a hot magma occurs, the above processes repeat. It is considered that hot magmas repeatedly inject at the same level and that no segregation between liquid and crystal occurs in our model. Additionally, effects of water in the hot magma were also taken into account. The hydrous hot magma melts the crust, solidifies itself, becomes saturated in water, and releases free water into the overlying crust.

We carried out calculation for a gabbroic crust that produces magmas by melting and assumed various F(T) of it. Calculation conditions are as follows. Initially, the surface temperature and temperature gradient of the gabbroic crust with 2 wt% water are 0 deg.C and 20 deg.C/km (the initial temperature of the melted is determined by its depth). Injected hot magmas have basaltic composition, the initial temperature of 1250 deg.C, and the initial water content of 2 wt%. Thickness of a single injection of the hot magma is 50 m. the critical melt fraction of convection is assumed as 0.6. In the calculation, we changed the injection depth of the hot magmas (pressure range is between 0.25-1.0 GPa) and injection rate of the hot magmas (2-20 m3/m2ky). The calculations for 300 ky are carried out.

The calculation results indicate that as a rate of increase of F(T) is smaller near the solidus, total amount of melt produced by crustal melting due to a certain amount of injected magmas becomes smaller while amount of melt produced with relatively low degree of partial melting becomes larger. Melts produced with relatively high and low degrees of partial melting are interpreted as mafic and silicic melts, respectively. Therefore, crusts that have a small rate of increase of F(T) near solidus are favorable to produce voluminous silicic magmas.

Keywords: crustal melting, silicic magma, melt fraction, gabbro, physical model