Amount, composition and timescale of magmas generated by melting in lower crust

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Magmatisms are various in continental margins and continental hot spots. Magmas with various petrologic features erupt at a certain volcano and are also different from other neighbor volcanoes. For the variety of the continental magmatism, magma genesis by crustal melting can be a key process. In this study, we try to understand variation of composition, amount, and generation timescale of magmas produced by melting of a lower crust due to hot magma injections using a one-dimensional physical model.

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. A characteristic of our model is that voluminous crustal melt close to the critical melt fraction tends to be produced.

We carried out calculations considering that gabbroic amphibolite with 2 wt. % water is melted by repeated injection of hot basaltic magmas with initial temperature of 1250 deg. C at 1 GPa. It is assumed that the critical melt fraction above which the materials are convective is 0.5. In the calculations, we change the initial temperature of the crust (500-700 deg. C) and injection rate (4-32 m/ky), thickness in a single injection (10-800 m), and water content (2-12 wt. %) of the injected hot magmas as parameters. It is assumed that the hot magmas repeatedly inject at the same level and that no segregation between melt and crystals occurs in our model.

The calculation results indicate that the generation of magma by crustal melting occurs on 10,000-year timescale and that various amounts of magma with various degrees of partial melting are generated by crustal melting for the four changed parameters. The injection rate of the hot magmas basically governs total melt amount produced by melting; larger injection rate produces larger amount of melt. On the other hand, the initial temperature of crust and the injection thickness of the hot magma affect the degree of partial melting of the crust. Thin intrusions in warm crust produces relatively much melt with small degree of partial melting (i.e. silicic melt) whereas thick intrusions in cold crust produces much melt close to the critical melt fraction (relatively large melt fraction) (i.e. mafic melt). These parameters can be some of factors governing the variety of the continental magmatism.