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Production of mafic and silicic magmas in lower mafic crust by repeated injections of hydrous hot magmas

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Recent studies on igneous activity at areas with continental crust suggest that crustal melting by injection of hydrous mantle-derived basalts is an important process. When a hydrous mafic magma is intruded into the crust and solidifies, it melts the surrounding crust, and simultaneously adds water exsolved due to solidification to the crust, resulting in decrease of melting temperature of the crust. This affects magma genesis by crustal melting. The purpose of this study is to qualitatively understand compositions and amounts of magmas produced by melting of mafic lower crust due to repetitive injections of hydrous hot magma from the mantle. Here, we report calculation results of a one-dimensional physical model.

The model on melting and heat transfer by Koyaguchi and Kaneko (2000) is followed. When a crust is melted by a hot magma injected into a crust, melt fraction of the crust is maximum just above the injecting magma and decreases upward. Just after the injection, large heat flux from the convecting injected magma rapidly melts the overlying crust up to the degree of partial melting large enough to convect. Thus the mixture of melt and crystals convects as a whole and expands the convecting region by melting of the crust. After that, the injecting magma and convecting region of partially-molten crust decrease in temperature, increase in solid fraction, and hence cease to convect. At this stage, heat transfer becomes only conductive. When a new injection of a hot magma occurs, the above processes repeat. On water transportation, it is assumed that water exsolved from melt supersaturated with water migrates upward and is absorbed by undersaturated melt.

The conditions of the model are shown in the following. Compositions of injecting magma and crust are same, basaltic. Melting relation of the basaltic material is modeled on the basis of the MELTS program. Pressure is 0.8 GPa, the initial crustal temperature is 500 deg. C, a hot magma with liquidus temperature and 20 m thick are intruded at the same level of the crust every injection. It is assumed that melts and crystals are not segregated and that critical melt fraction of melt-crystal mixture between convection and non-convection is 0.5. Under these conditions, we changed two parameters, injection rate (2, 5, 10, and 20 m/ky) and initial water content (2, 3, 4, 6, and 10 wt.%) of the injecting magma. Calculation results show qualitatively different four regimes on features of melting processes.
(1)Case of small injection rate (2 m/ky) of the injecting magma: Because small heat is supplied by the injecting magma, the region with high degree of partial melting (i.e. region with mafic melt) forms little. Heat conduction slowly expands region with low degree of melting (i.e., region with silicic melt).
(2)Case of large injection rate (> 5 m/ky) and small water content (2-4 wt.%) of the injecting magma: The region with high degree of melting expands with time, whereas the overlying region with low degree of melting migrates upward but do not increase in thickness.
(3)Case of large injection rate and moderate water content (6 wt.%): Because water supplied from the injecting magma is almost absorbed by melt in the region with high degree of melting, the

region with high degree of melting is maintained even in lower temperature and cannot melt the overlying region with less water content. Then, only the region with low degree of melting slowly expands with time.
(4) Case of large injection rate and high water content (10 wt.%): Large amount of water is widely supplied to crust and make melting temperature of the whole crust decrease. Then, the region with high degree of melting expands every injection of the hot magma rather than the region with low degree.
Conditions of injecting magmas affect amount and composition of magmas generated by crustal melting. This may concern varieties of eruption rates and magma compositions in individual volcanoes.

Keywords: crustal melting, gabbro, mafic crust, water transportation, hydrous basaltic magma