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Carbon isotopic variation during CO2 fluxing in crustal magmatic systems

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#Introduction

Geochemical studies on glass inclusions trapped in phenocrysts suggest that shallow-stored crustal magmas often suffer the open-system addition of a CO2-rich vapour from below, probably from a mantle-derived basaltic source (CO2 fluxing) (e.g., Metrich and Wallace, 2008). This proposal was made because the CO2/H2O compositional ratio of the inclusions cannot be explained by conventional degassing models. The CO2 fluxing is of importance in various geological settings. First, the fluxing may be the principal process that transfers carbon stored in the earth's interior to the atmosphere in the global carbon cycle. Second, the fluxing controls various igneous processes including crystallization and viscosity of a melt, because it reduces activity of water. Third, the fluxing may trigger a volcanic eruption, because it dramatically increases vapour fraction and thus decreases bulk density of the magma (Yoshimura and Nakamura, 2010). However, the mechanism of CO2 fluxing is scarcely understood.

Recently, we have formulated the CO2 fluxing as a reactive transport process and showed its fundamental properties. Such modelling enabled us to discuss the mechanism of vapour transport quantitatively (Yoshimura and Nakamura, submitted). In this study, we updated the model so that it might include carbon isotopic evolution (d13C) of the melt and vapour.

#Reactive transport modelling

The model assumes that a CO2-rich vapour with a fixed chemical and isotopic composition is continuously introduced into a water-rich, vapour-presaturated melt column at a constant rate. The introduced vapour ascends upward at a constant velocity. Because this vapour is initially in chemical and isotopic disequilibrium with the melt, a volatile exchange takes place. The initial column is assumed to have the H2O-CO2 and d13C compositions formed by closed-system degassing, which evolved from the bottom magma to various extents dependent upon pressure.

The governing equations consist of advection equations for H2O, 12CO2 and 13CO2, the solubility law of H2O-CO2 and an equation of isotopic equilibrium between 12CO2 and 13CO2. We assumed that the interaction is achieved instantaneously at each level of the column.

#Results and discussion

As was shown in Yoshimura and Nakamura (submitted), the melt gradually became CO2 rich, while the vapour was diluted with H2O that was discharged from the melt. Whilst the H2O-CO2 chemical exchange was still in progress, the isotopic equilibration was achieved in a very short duration. When the first packet of the introduced vapour reached the top of the column, nearly whole the melt column had a constant d13C value that is in equilibrium with the introduced vapour. The reason for such a quick isotopic equilibration is that the amount of 13CO2 and 12CO2 exchanged between the melt and vapour is extremely small compared with the amounts of each isotope originally contained in both phases. Such isotopic information will enable us to discuss more detailed mechanism and the source of CO2, if d13C values in glass inclusions and volcanic gases are observed in the future.

Keywords: CO2 fluxing, degassing, reactive transport