

## Carbon isotope evolution in magmatic systems by CO<sub>2</sub> fluxing

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Simple degassing models often fail to explain the high CO<sub>2</sub>/H<sub>2</sub>O ratio of melt inclusions and obsidian pyroclasts. This suggests that the fluxing of a deep-derived CO<sub>2</sub>-rich fluid is common in crustal magmatic systems (e.g., [1]). This process, called "CO<sub>2</sub> fluxing", is believed to be a combination of the advective flow of a CO<sub>2</sub>-rich fluid through a magma column and the resulting volatile exchange. However, other processes, such as closed-system equilibrium degassing under the presence of a buffering CO<sub>2</sub>-rich fluid [2] and disequilibrium open-system degassing [3], can explain such data. In this study, we show that carbon isotope ( $\delta^{13}\text{C}$ )–CO<sub>2</sub> systematics may discriminate these processes.

We present a theoretical framework of carbon isotope evolution caused by CO<sub>2</sub> fluxing based on a reactive transport model. We assumed that a CO<sub>2</sub>-rich fluid with a constant CO<sub>2</sub>/H<sub>2</sub>O ratio and a constant  $\delta^{13}\text{C}$  value is introduced into a magma column and flows upward through the column, exchanging volatile components chemically and isotopically with the melt. The governing equations consist of an advection equation, the solubility law of CO<sub>2</sub>-H<sub>2</sub>O and an equation of isotope equilibration. The equilibrium volatile exchange is assumed at each level of the column.

The calculations show that initial carbon isotope distribution is immediately modified as the fluxing proceeds. When the first incremental of the introduced fluid reached the top of the column, the  $\delta^{13}\text{C}$  value was almost constant along the column, whereas CO<sub>2</sub>-H<sub>2</sub>O concentrations were still changing towards entire equilibrium between the magma and the introduced fluid. These results are in contrast to those for other processes such as equilibrium degassing where  $\delta^{13}\text{C}$  decreases as degassing proceeds, or disequilibrium degassing where  $\delta^{13}\text{C}$  is expected to increase because <sup>12</sup>CO<sub>2</sub> may diffuse faster than <sup>13</sup>CO<sub>2</sub>.

[1] Métrich & Wallace (2008) *Reviews in Mineralogy and Geochemistry* **69**, 363–402. [2] Newman *et al.* (1988) *J. Volcanol. Geotherm. Res.* **35**, 75–96. [3] Gonnermann & Manga (2005) *Earth Planet. Sci. Lett.* **238**, 1–16.

## Temperature dependence of Mg isotope fractionation in deep-sea coral:

## Paleoceanographic implication as a new proxy for water temperature

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This study presents magnesium isotopic composition and its temperature dependence of high Mg biogenic calcium carbonates to evaluate their potential proxy of paleo seawater temperature. Degrees of Mg isotope fractionation compared to present seawater were measured in deep-sea coral. The mean  $\delta^{26}\text{Mg}$  value of deep-sea corals was  $-2.5\%$ . Moreover, Mg isotope fractionation in deep-sea coral showed a clear temperature dependence from 2.5 to 19.5 °C. The observed temperature dependence of Mg isotope fractionation in deep-sea coral skeletons allows potential application of Mg isotopes of high-Mg calcite to an environmental proxy for water temperature, and one possible way for robust temperature reconstruction is a multi-proxy approach which provides complementary and more robust temperature data using traditional and non-traditional temperature proxies. The mean  $\delta^{26}\text{Mg}$  value of large benthic foraminifera which are also composed of high-Mg calcite was  $-2.34\%$ . Deep-sea coral and benthic foraminifera both plot on the same regression line within uncertainty. Deep-sea corals and benthic foraminifera also showed similar Mg isotope fractionation factor to inorganically precipitated calcite, and the slope of temperature dependence in Mg isotope fractionation is similar to that for an inorganically precipitated calcite speleothem. Moreover, Mg concentrations and the relationship between Mg/Ca and temperature were also similar between deep-sea corals and inorganically precipitated calcite. Taking into account elemental partitioning and the calcification rate of biogenic CaCO<sub>3</sub>, the similarity among inorganic minerals, deep-sea corals and benthic foraminifera may indicate a strong mineralogical control on Mg isotope fractionation for high-Mg calcite.