A condition of degassing magma deduced by the chemical and isotopic ratio of fumarolic gas

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The inside of active volcano is a complex system. The chemical constituent and enthalpy are provided by a degassing magma. The degassed volatile species inevitably encounter the groundwater, resulting in the formation of magmatic-hydrothermal system. The vapor and the conjugated liquid phases co-exist in the hydrothermal system. A part of vapor phase is discharged and noticed as fumarolic gas at surface of geothermal area. The importance of fumarolic gas depends on the fact that fumarolic gas carries the information on degassing magma and hydrothermal system. Among the components of volatile, SO2, H2S, HCl interact with groundwater and are modified significantly in terms of their contents. The CO2 is expected to be less modified because CO2 is less soluble in water and cannot be removed as mineral deposit in acidic environment which is typical to magmatic-hydrothermal system. As the most abundant specie, H2O is contaminated by groundwater, however, the degree of contamination could be evaluated based on the D/H and 18O/16O ratios.

In the hydrothermal system, the dominant interactions of volatile are, the mixing with groundwater and the separation of vapor and liquid phases. Based on the CO2/H2O ratio and isotopic ratio of H2O of fumarolic gas, the CO2/H2O ratio of degassed volatile can be evaluated assuming the following conditions: the conservation of enthalpy, the conservation of amount and isotope for CO2 and H2O, and the equilibrated distribution of CO2 and isotope between vapor and liquid phase. The above evaluation was applied to the fumarolic gases of active volcanoes in Japan. The CO2/H2O molar ratio was 0.03 in 1994 for the gases at Shinmoedake volcano at Kirishima, which has erupted in 2012. The fumarolic gases at Kusatsu-Shirane and Atosanupuri results in low value as much as 0.06. Those volcano has been dormant with persistent discharge of fumarolic gas. At Hakoke volcano, a temporal variation in the evaluated CO2/H2O ratio has been observed. In 2001, the ratio increased to 0.021 but deceased to 0.004 in 2005. In 2001, volcanic earthquakes were observed at Hakone volcano the number of which was significant relative to quiescent period.

The CO2/H2O molar ratio evaluated from the composition of fumarolic gas provides a useful information for a degassing magma. The high CO2/H2O ratio of degassed gas suggests the high CO2 content in magma chamber. As the CO2 is less soluble component in silicate melt, CO2 preferentially leaves the magma chamber through degassing. The increase in CO2 content in magma chamber suggest two possibilities. One is the replenishment of new magma enriched in CO2 gas provided by a source connected to the magma chamber. Another is the accumulation of bubbles in the roof magma chamber. In the gas phase of bubbles, CO2 is enriched relative to H2O. The degassed gas phase contributed by the bubbles should be enriched in CO2 gas.