Attempt to obtain the information on magma based on the chemical, isotopic and rare gas composition in fumarolic gases

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Some volcanoes are classified into active volcanoes in Japan based on its fumarolic activity, even if they have no historical eruption (e.g., Mt. Hakone). The evaluation of the eruptive potential for such a volcano is important in term of the mitigation for volcanic disaster over long term. The potential of eruptive activity would be provided by the concentration of volatile and amount of bubbles in magma.

If the concentration and the amount is enough high, the magma will start to uprise due to the buoyancy.

However, there is no way to evaluate the amount of volatile in magma directly. The concentration of volatile in magma deduced by melt inclusion analysis is only the concentration of magma responsible for previous eruptions. CO2 gas has the solubility in magma much lower than H2O. CO2 gas is preferentially distributed into gas phase even at the depth where magma is situated. Therefore, a stagnant magma would emit high temperature gas the CO2/H2O ratio of which decrease along the progress of degassing. The CO2/H2O ratio of gas originating in a degassing magma could be useful information on the potential of stagnant magma.

The high temperature gas from degassing magma creates a hydrothermal system in volcanic body. At first, the high temperature gas is mixed with a deep circulation ground water resulting in a formation of hydrothermal fluid. The hydrothermal fluid uprises to shallow space, then, boils. The vapor phase generated from the boiling hydrothermal fluid is discharged as fumarolic gas. At near surface, the vapor phase again interacts with ground water, and the H2O vapor is partially condensed near surface (Ohwada et al., 2003, Sawa et al., 2006).

The high temperature gas emitted from magma undergoes the above multiple interaction with meteoric ground water. In this study, we intend to solve the complicated process between magmatic gas and meteoric ground water based on the chemical composition, H2O isotopic ratio and rare gas composition in fumarolic gas, and also we intend to estimate the CO2/H2O ratio of the magmatic gas.

For the analysis of the process, the following parameters are useful because they have the specific value characteristic to each magmatic gas and meteoric ground water.

18O/16O ratio of H2O: magmatic gas=+8 to +10 permil, ground water=-5 to -8 permil
36Ar/H2O ratio: magmatic gas=0, ground water=7.4E-10
CO2/H2O ratio: magmatic gas is larger than zero, ground water=0

A model calculation suggests that the vapor phase created after the interaction between magmatic and meteoric water has CO2/H2O and 36Ar/H2O ratios principally higher than the ratios of magmatic gas because a part of H2O vapor in magmatic gas decrease due to condensation and CO2 and 36Ar is preferentially distributed in vapor phase. The 18O/16O ratio of vapor phase is lower than the ratio of magmatic gas because the mixing with meteoric ground water with low 18O/16O ratio. The relationships among the parameters observed in the chemical composition of fumarolic gas were generally consistent to the model calculation. The relationship between 36Ar/H2O and 18O/16O ratios of fumarolic gas gives a mixing ratio of magmatic gas and meteoric ground water.

The mixing ratio can be used for the estimation of CO2/H2O ratio of magmatic gas.

The CO2/H2O ratio of magmatic gas from Mt. Kusatsu-Shirane, Mt. Hakone and Tatun volcanoes, Taiwan was estimated to be 0.006, 0.0055 and 0.031, respectively, along the above method.

In general, the feature of fumarolic gas discharge is variable. A strong fumarolic gas is discharged with large noise. A weak fumarolic gas is discharged with no sound. In our observation, the strong fumarolic gas could be used for the estimation of magmatic CO2/H2O ratio. Weak fumarolic gases were found to be modified in term of the chemical and isotopic ratio because of the effect of condensation of H2O vapor and interaction with shallow ground water.