Time variation in the volcanic gas at Hakone volcano with the interpretation

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Introduction
At Mt Hakone, the swarm of volcanic earthquakes happed in June to Oct 2001 with the pressure increase of steam discharged from boreholes drilled in Owakukdani geothermal area. A similar phenomenon happened in the end of April 2015. During the occurrence of earthquake swarm in 2015, a small steam eruption happed in Owakudani geothermal area. We should expect another earthquake swarm and eruption at Mt Hakone in future. In general, the chemical composition and isotope ratios of volcanic gas change along the progress of volcanic activity. The prediction of earthquake swarm based on the volcanic gas contributes the mitigation of volcanic hazard at Mt Hakone. In this study, we report the chemical composition and isotope ratios of fumarolic gas sampled at Mt. Hakone since May 2013, and try to interpret the time variation.

Fumarolic gas
We have sampled two fumarolic gas at fixed location with the frequency of once per month. One point of sampling is located within Owakudani geothermal area. Another point of sampling is located in Kamiyuba geothermal area, 500m far from Owakudani gothermal area in north direction.

Result and discussion
A significant increase in CO2/H2O ratio happed in May 2015, at the both fumarolic gas, which synchronized with the start of volcanic earthquake swarm. The increase could be brought by the development of sealing zone surrounding a degassing magma. The sealing of degassing magma increases the pressure of magma and also increases the CO2/H2O ratio of gas equilibrated with magma. A magmatic fluid with high CO2/H2O ratio would be injected to the shallow hydrothermal system after the break of developed sealing zone. The injection produced the earthquake swarm, the pressure increase in steam from bore holes, and the increase in CO2/H2O ratio of fumarolic gas.
Before the earthquake swarm in April 2015, a significant increase in N2/He ratio was observed. The increase started in Feb 2015, being kept until the start of earthquake swarm. The change can be also explained by the magma sealing model. Before the break of sealing zone, the supply of magmatic fluid to the shallow hydrothermal system had been suppressed. The fluid pressure in the hydrothermal system was lowered by the suppression, which induced the invasion of atmospheric air from surface. The contaminated air was involved in the fumarolic gas, which caused the increase in N2/He ratio.
The fumarolic gas from Mt Hakone contains H2 gas and H2O vapor. An apparent equilibrium temperature (AET) can be calculated by use of D/H of H2O and H2. The AET was stable with average around 100C before Aug 2014 for both fumarolic gases, and dropped to 70C after Sep 2014. The drop continues about 2 months. During the occurrence of volcanic earthquake in 2015, AET increase to 130C in average. After the earthquake, AET was stabilized to 110C in average. The drop of AET may be a precursor for the earthquake swarm in 2015.

Keywords: Volcanic gas, Mt Hakone, Eruption

