Variation of fumarolic gas composition along the volcanic activity of Mt Hakone, Japan

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The driving force of eruption is the degassing of magma or the explosion of hydrothermal reservoir. The volcanic gas contains the component originating in the degassing magma or the hydrothermal reservoir. Therefore, the volcanic gas is essentially important object for the understanding of eruption and the eruptive prediction.
At Mt Hakone, the swarm of volcanic earthquakes has been observed previously. For example, in 2001 the swarm of volcanic earthquakes was observed with the deformation of volcanic body suggesting a pressure source the depth of which was estimated to be 7km (Daita et al, 2009). In parallel to the swarm of earthquakes, the steam pressure in the borehole located in the geothermal area of Owakudani significantly increased. On 26th April 2015, a swarm of volcanic earthquake has started. On 30th June, a small steam eruption took place in the Owakudani geothermal area, which is the first historical eruption at Mt Hakone. The number of earthquake quickly decreased until September of 2015.
Sampling and analysis of fumarolic gas
The Owakudani geothermal area is developed on Mt Kamiyama, one of the central cones of Hakone caldera. The fumarolic gases have been sampled and analyzed at two outlets in Owakudani geothermal area almost every month since May 2013 to Feb 2016. One fumarolic gas (T) is located near the parking of Owakudani geothermal area. Another fumarolic gas (S) is located on the north flank of Mt Kamiyama, 500m far from the fumarole T. The temperature of gas at the outlets was about 96C, which is close to the boiling temperature of the altitude of the fumaroles. The fumarole T associates the discharge of hot spring water. The fumarolic gas was sampled in the evacuated glass bottle containing 20ml of 5M KOH solution. For the determination of SO2/H2S ratio, KIO3-KI solution was reacted with fumarolic gas at the sampling site. For the sampling of condensed water of gas, a double glass tube was used for cooler. The solution in the evacuated glass bottle was analyzed along the method by Ozawa (1968) to determine the amount of H2O, CO2, total S (=H2S + SO2) and R-gas. The R-gas was analyzed by GC with Ar and He carrier gases to determine the relative concentration of He, H2, O2, N2, CH4 and Ar. The isotopic ratio of condensed water was determined by use of an IR-laser cavity ring down analyzer (Picarro).
Result and Discussion
Prior to the small steam eruption on 30th June 2015, definite changes were detected in the composition of fumarolic gas-T. The isotope ratio of H2O (dD) was -51 per mill in Jan 2015. It decreased to -67 per mill on 24th April which was 2 days before the start of earthquake swarm. After the start of earthquake swarm, it increased to -56 per mill on 8th May. Similar to the above change, He/N2 ratio showed precursory change. The ratio was 3.3x10-4 in Dec 2014, followed by the decrease down to 1.1x10-5 on 24th April 2015. The ratio came back to 2.8x10-4 on 8th May. The changes in dD and He/N2 ratio suggest the suppressed supply of magmatic H2O into the shallow hydrothermal system. The suppression might be brought by the development of sealing zone surrounding the degassing magma. The sealing zone is a structure in crust where hydrothermal secondary minerals, such as silica, pyrite, alunite, anhydrite, deposit within the channel of fluid. The deposition of those minerals seals the channel by themselves. If the sealing is complete, the degassing fluid is stored within the sealing zone. The break of the sealing zone episodically injects the magmatic fluid to the shallow hydrothermal system. The increase of fluid

pressure after the injection induced the earthquake swarm stated on 26th April 2015.

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