Change in the chemical and isotopic composition of volcanic gases from Owakudani geothermal area of Mt. Hakone, Japan

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1.Introduction

Mt. Hakone is a caldera volcano located at the western end of Kanagawa prefecture. The volcano has the central cone on the floor of caldera. The height of the cone is 1438m from sea level. On the north flank of the central cone, Owakudani geothermal area is located at the altitude of 1000m.

In Jun. to Nov. of 2001, earthquake swarms were observed under the central cone (Tanada et al. 2001). In Jun. 2001, an inflation of crust was observed near the central cone. The pressure source for the inflation was estimated to be located at the depth of 5 km. And 2x10ˆ6 mˆ3 of volume increase was estimated at the source (Nishimura and Murakami, 2001).

Hakone-Onsen-Kyokyu KK (hereafter HOK) has provided the 'artificial hot spring water' to local hotels since 1930 at Owakudani geothermal area. The artificial hot spring water has been produced by the mixing of cold meteoric water and hot steam in a drum. The steam has been gained from bore holes. HOK has dug many bore holes at Owakudani geothermal area. One bore hole No.52 has the end reaching the depth of 800m from surface. On 19th Jul. 2001, the outlet pressure of No.52 increased significantly, then, the drum for artificial hot spring was broken.

We carried out repeated gas samplings and analysis at No.52 bore hole and a natural fumaroles located 250 m far from the No.52 bore hole. In this study, we interpret the change of the chemical and isotopic composition of gas in the context of correlation to volcanic activity of Mt. Hakone.

2. Result of observation at No.52 bore hole

The drum for artificial hot spring was rebuilt in 2002. We can estimate the flux of steam from bore hole based on the temperature of steam and hot water, and the influx of cold water. The flux was 207 ton/day in 2002. The flux drastically decreased after 2002. The temperature of steam was 163.3deg.C in 2002. The temperature decreased to 136deg.C in 2003. The temperature increased gradually after 2003, then, reached 152deg.C in 2005. The temperature decreased to 143C in Nov. 2006. The CO2/H2O ratio of steam showed a pattern opposite to the temperature. The 18O/16O ratio of H2O did not show a simple pattern with a variation between +0.6 and +4.9 permil to SMOW.

3. Result of observation at the natural fumarolic gas

The temperature of fumarolic gas was stable with a small variation between 95.5 and 97.8deg.C. The CO2/H2O ratio was low in 2001. The ratio increased in 2002 then decreased gradually until 2005. The ratio increased in 2006 relative to 2005. The C/S elemental ratio of gas showed the pattern similar to the CO2/H2O ratio.

4. Discussion

The CO2/H2O ratio of steam from No.52 was unstable with a large variation between 0.0067 and 0.028. Such a large variation can be explained by a condensation of H2O vapor. This explanation is consistent to the change in the temperature. The intense cooling of steam brings the effective condensation of H2O vapor and the increase in CO2/H2O ratio. The pattern of CO2/H2O ratio observed in the No.52 steam and the natural fumarolic gas was almost common, suggesting their common source.

In Nov. 2006, the CO2/H2O ratio of No.52 and the fumarolic gas increased simultaneously. The steam flux in Nov. 2006 did not increase relative to 2005, suggesting no activation of magma degassing. In Sep. and Oct. 2006, earthquake swarms took place under the central cone. We speculate that the earthquake produced cracks around the channel of volcanic gas. The cracks might increase the surface area of channel at which volcanic gas contacts with a cold crust, resulting in an effective cooling and condensation of H2O vapor in volcanic gas. Based on the above speculation, the increased CO2/H2O ratio in Nov. 2006 was a response to the earthquake swarms in Sep. and Oct. 2006.