

## 論文の内容の要旨

Controlling factors on hydrothermal fluid ascent in a volcanic edifice revealed  
by diffuse CO<sub>2</sub> flux measurements: A case study of Asama volcano, Japan  
(土壌拡散の CO<sub>2</sub> 放出量測定にもとづく火山体内部での  
熱水流体上昇を支配する要因の解明—浅間火山での事例研究—)

氏 名 森田 雅明

Magmatic volatiles are considered as driving force of eruptions and have impact on the environment when emitted to the atmosphere. Thus, evaluations of volatile emissions from the volcanoes are important to monitor the volcanic activity changes and to assess their impact on the environment. Among the major magmatic volatiles, CO<sub>2</sub> is the first volatile to exsolve from the melt due to its low solubility in the melt, thus measurements of the CO<sub>2</sub> emission are considered important for monitoring volcanic activities, especially to detect the early activation of the volcano. Volcanic CO<sub>2</sub> are emitted into the atmosphere not only as high temperature volcanic plume from active craters but also as invisible emission from the volcano flanks called diffuse CO<sub>2</sub> emission. Recent compiled data of volcanic CO<sub>2</sub> emissions [e.g., *Burton et al.*, 2013, Rev. Min. Geochem.] indicated that the diffuse CO<sub>2</sub> emissions are an important source of emissions comparable to the plume CO<sub>2</sub> emissions.

The diffuse CO<sub>2</sub> degassing can be treated as consequences of the hydrothermal fluid ascent in the volcano flanks. The area of the anomalous diffuse CO<sub>2</sub> emission is called diffuse degassing structures (DDS). Numerous previous works found the relation between the DDS and regional tectonic or volcano-tectonic structures. Additionally, a recent study on the distribution of fumarolic areas by *Schöpa et al.* [2011, J. Volcanol. Geotherm. Res.] clarified that the topography and lithology controls as well as the structure control are effective controlling factors of the hydrothermal fluid ascent. However, little is known about the topography control on the DDS distribution.

The objectives of this study are to reveal the controlling factors on the diffuse CO<sub>2</sub> degassing, especially the influence of the topography control, and to examine the possibilities of other controlling factors on the diffuse CO<sub>2</sub> degassing. For the objectives of this study, summit area of Asama volcano, Japan, was selected as the study area, which was mainly set in Maekake crater (the outer crater), the

summit area of Asama volcano.

The surveys of diffuse CO<sub>2</sub> flux at the summit area of Asama volcano were conducted six times during 2012–2016. Four surveys with total of 211 measurements were conducted in the inactive period. Two surveys with total of 80 measurements were conducted in October 2015 and August 2016 during the active period after the minor eruptions in June 2015. In the 2016 survey, soil gas samples were also collected and analyzed for chemical and isotopic compositions at selected measurement sites.

Statistical analysis based on the graphical statistical approach (GSA) was applied to the observed soil CO<sub>2</sub> flux values of the summit area in the inactive period, and spatial distributions of the soil CO<sub>2</sub> flux values were constructed using sequential Gaussian simulation (sGs). The soil CO<sub>2</sub> flux distribution of the inactive period showed an E–W heterogeneous distribution at the summit area and a N–S elongated elliptical-ring shape DDS was found only in the eastern side of the study area. In the northern, southern, and western parts of the study area, the soil CO<sub>2</sub> flux values were basically negligible except for a small area on western Maekake crater wall.

The ring shape of the DDS is likely explained both 1) by the volcano-tectonic structures corresponding to hidden fractures of the two collapsed craters, which formed present Maekake crater, and 2) by the topography control as revealed by spatial comparisons between the DDS distribution and the topographic position index (TPI) map, which was introduced to extract the local crests of the summit area.

The E–W heterogeneity of the CO<sub>2</sub> flux distribution and the  $\delta^{13}\text{C}$  values of soil CO<sub>2</sub> indicated that other controlling factors except for the structure, lithology, and topography controls should also be considered for the summit area of Asama volcano. A comparison between the electrical resistivity structure of Asama volcano and the results of this study showed that the low-resistive body at shallower depth under the eastern side of Maekake volcano corresponds to hydrothermal fluids as the source of the diffuse CO<sub>2</sub>. The comparison also suggested that the negligible or very small diffuse CO<sub>2</sub> emission in the western part may be explained by the very weak connection of the hydrothermal source to the ascending pathways of the fluids due to larger depth of the hydrothermal source and/or sealing clay-rich mineral layers, or by the low amount of the hydrothermal fluids in the western side. The presence of both the hydrothermal source and the connection from the hydrothermal source to the ascending pathways are probably an important factor to form the observed E–W heterogeneous diffuse CO<sub>2</sub> distribution at the summit area of Asama volcano, which may also be important for other volcanoes.

Based on previous studies and this study, a schematic model of the degassing system of Asama volcano in inactive periods was suggested. This study revealed that a total emission rate of diffuse CO<sub>2</sub> from the summit area of Asama volcano was 12.6 t day<sup>-1</sup> in the inactive period, and that such significant amount (about 12 % of total CO<sub>2</sub> emission) is emitted as diffuse CO<sub>2</sub> from the eastern part of the summit area. The diffuse CO<sub>2</sub> emission observed only in the eastern side of the summit area is important for understanding the structural framework of Asama volcano. Thus, further repetitive surveys of diffuse CO<sub>2</sub> emissions in this area would be important to understand the development of the hydrothermal system of the volcano. Moreover, the diffuse CO<sub>2</sub> flux values of the active period in the eastern part of Maekake crater rim showed significant increase from those of the inactive period. Hence, the eastern Maekake crater rim may be an effective site for monitoring the volcanic activity by the continuous diffuse CO<sub>2</sub> flux measurement in the future.