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Electrical conductivity structures of volcanic areas: a proxy for volcanic gas fluxes

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The efficiency of degassing of volcanic gases in magma is one of the key parameters controlling the explosive potentiality of the eruption and the diversity of the volcanic activity. Therefore, to evaluate the mass flux of volcanic gases is important in considering the constraint conditions of the activity. When volcanic gases are dissolved into the pore water of an aquifer, the aquifer has a high electrical conductivity (E.C.); this is because that the pore water conductivity is increased due to the high-salinity and temperature, and that the surface conductivity of rock matrices is also increased due to hydrothermal alteration. Therefore, the spatial extent of the high E.C. region could be related to the abundance of the mass flux of volcanic gases. We have developed the method to estimate the mass flux of volcanic gases using the E.C. structure of volcanic areas as follows.

[Effect of exposure temperatures on the surface conductivity of rock matrices]
There has already been some quantitative formula about the effect of temperature and salinity on the E.C. of the pore water. On the other hand, it has been known that temperatures are closely related to the generation/stability of smectite, which makes a great contribution to the increase of E.C. However, their effect on the surface conductivity has not been understood quantitatively. We performed the E.C. measurements using drillcore samples obtained from drilling projects, to estimate the surface conductivity. Results showed that the relation between surface conductivities and the temperatures to which the rock matrices have been exposed well corresponds to generation/stable condition of smectite. Thus, the surface conductivity could be represented as relatively simple function of exposure temperatures, and the formula could be incorporated into the modeling of dissipation of volcanic gases (Komori et al., 2010, 2013).

[Simplified model for the dissipation of volcanic gases and its application to Unzen volcanic area]
In Unzen volcanic area, there are various geophysical and geochemical studies to understand the formation process of hot springs associated with magma degassing and the magmatic activity. Ohba et al. (2008) proposed three-stage magma degassing; the first magma degassing occurs at the depths of 4-6 km. Correspondingly, the pressure sources are estimated at the similar depths (Kohno et al., 2008). In addition, the high temperature region greater than 200 ℃ are present above the sources (NEDO, 1988), which corresponds to the high E.C. region inferred from TDEM surveys (Srigutomo et al., 2008).
Based on the above background, we developed the simple model of volcanic gases dissipation into the aquifer at the area, to estimate the mass flux of volcanic gases. The model assumes the isotopic physical properties and the simple geometry of the aquifer. The temperatures and salinity of the pore water are distributed by the simulated flow regime, which is the consequent of the injection of the thermal waters formed by the mixing between volcanic gases and groundwater. Their distributions are converted to the pore water and surface conductivities; which are then converted to the bulk E.C. Results showed that the spatial extent of the high E.C. region is essentially controlled by the volcanic gases flux and rainfall recharge (Komori et al., under review).

[Possibility of effective magma degassing]
The above model was applied to the E.C. structure of the area. The estimated volcanic gas flux was 10ˆ4.8$\pm$0.5 t/yr, yielding the CO_2 flux (10ˆ3.1$\pm$0.5 t/yr) and the magma input rate (10ˆ0.1$\pm$0.5 million t/yr). These values are consistent with other petrology, geochemical and geophysical evidences. Our result suggests that the magma is steadily releasing the volcanic fluids into the aquifer. This effective degassing might lead to the decrease of water content of magma, and be one of the reason of the recent effusive volcanism like dome-forming eruptions (Komori et al., under review).

Keywords: Bulk electrical conductivity, Pore water conductivity, Surface conductivity, Volcanic gas fluxes, Unzen volcanic area