Conductive and convective heat fluxes inferred from temperature profile of a borehole in Izu-Oshima volcano

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A 1,000 m-deep borehole was drilled at the western rim of the caldera of Izu-Oshima volcano by Earthquake Research Institute, University of Tokyo in 1998. Temperature profiles of deep borehole provide information of subsurface heat and groundwater flows, which are clues to understand structure of geothermal fluid systems in volcanic and geothermal areas. Here, conducive and convective heat fluxes of Izu-Oshima volcano are estimated by using the temperature profile data.

A wellhead altitude of the borehole is 547 m, so as that the bottom depth is 453 m bsl. The borehole penetrates main strata in this area. Above the sea level, the edifice is mainly composed of the alternation of scoria, lava and volcanic ash (“Post-caldera” and “Pre-caldera younger edifice”). Tuff breccias become dominant approximately below the sea level (“Pre-caldera older edifice”). “The basement”, which comprises altered volcanic and volcaniclastic sedimentary rocks, appears from 250 m bsl. to the well bottom (Nakada *et al.* 1999).

Groundwater level is 36 m asl. Thus, about 500 m of a thick unsaturated zone develops above the level. Characteristics of the ground temperature profile are divided at the groundwater level. In the unsaturated zone, 16-17 degC of a constant temperature continues at depths of ca. 50-350 m (ca. 500-200 m asl.). From 200 m asl. to the groundwater level, the temperature gradient gradually increases. This downward convex pattern of the temperature profile implies a strong downward flow of meteoric water infiltrating into the unsaturated volcanic edifice. At the groundwater level, the temperature is about 37 degC. Below the level, ca. 0.28 degC/m of a steep temperature gradient is observed, reaching 173.3 degC at the well bottom. The gradient is not constant but seems to be two upward convex patterns implying upward flows of groundwater.

The temperature profile in the saturated zone below the groundwater level was analyzed. The temperature gradients seem to depend on the lithology. Therefore, correction of lithology should be conducted to quantitatively extract information on the convective heat fluxes. Since a bulk density has been inferred by borehole gravimeter measurements in intervals of about 10 m, the porosity for each depth can be calculated by assuming densities of the rock without pore and water filling the pore. The bulk thermal conductivity for each depth was calculated by a relationship proposed for porous basaltic rocks by Robertson (1988).

The temperature profile data were analyzed by assuming a one-dimensional steady vertical groundwater flow. The model was applied to two depth ranges; 1) upper part of the Pre-caldera older edifice, and 2) the basement. In the upper part of the Pre-caldera older edifice, *Pe* = 0.91 of the Péclet number was obtained, suggesting the convective heat flux is comparable to the conductive heat flux. The estimated conductive and convective heat fluxes and the Darcy velocity are 0.45 –0.56 W/m^2, 0.41 –0.51 W/m^2 and (1.42-1.78)*10^{-6} m/s, respectively. In the basement layer, as compared to the upper part of the older edifice of pre-caldera, *Pe=0.31-0.41* of smaller Péclet numbers were obtained, suggesting that the conductive heat flux is dominant. The conductive and convective heat fluxes and the Darcy velocity are 0.32 –0.39 W/m^2, 0.12 –0.13 W/m^2 and (4.71-4.98)*10^{-7} m/s, respectively.

Honda *et al.* (1979) inferred 0.2 W/m^2 of the conductive heat flux at the depth of 500-700 m (within the basement layer) at the northwestern coastal area. The estimated flux is about three times of the averaged terrestrial heat flux. The conductive heat flux within the basement layer in the caldera region inferred by this study is one and a half times to twice of the flux at the coastal area. The convective flux is added to this. When these heat fluxes are applied to 100 km^2 of the area (approximately whole the island scale), the total heat flow is estimated as to be 20-51 MW.

Keywords: Izu-Oshima volcano, temperature profile, heat flux, groundwater