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## Flow of thermal and groundwaters in the Owakidani and Gora area, Hakone

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Oki and Hirano (1970) proposed a synthetic model that combines formation and flow of thermal waters in Hakone caldera with the uprising of volcanic gases, structure of base rocks and thermal conditions. To explain the model simply it is occasionally expressed as "hot eye and cold eyelid". The expression describe their idea that cold stratified ground waters are being warmed while they flow from the west around Lake Ashinoko toward the east through the hot region (hot eye) beneath central cones where volcanic gases are rising from magma reservoir existing in the depth. However, having examined in detail data about hydraulic head in the Gora area obtained in the period from 1960 through 2000, Machida et al. (2007) considered that ground waters are rather flowing vertically toward the depth, although the flow has also a component parallel to the inclination direction of the topography. Based on the result, they presented an idea that the zone in the WNW-ESE direction where hot NaCl springs are distributed is not related to the stream of volcanic hot water as considered by the Oki and Hirano model, but represents the extension of the area where reservoir of volcanic hot water rich in NaCl is underplayed,

By having examined concentrations of major anions and their relative concentrations as well as relationships between the oxygen isotope ratio and each concentration of those anions for thermal waters that are flowing out in Gora and Sokokura in detail, we (Kikugawa et al., 2010; Itadera et al., 2010) presented a new model to classify thermal waters in the areas that differs from the Oki and Hirano model. In the new model, existence of  $\text{HCO}_3^-$  in the Zone II springs in the Oki and Hirano model is attributed to the mixing of volcanic gases into the ground water recharged in the site. On the other hand, in the Oki and Hirano model origin of  $\text{HCO}_3^-$  in the Zone II springs was regarded as organic matters buried in the Hayakawa tuff breccia. We consider, as like Machida et al. (2007), that the belt-like zone in the WNW-ESE direction where hot springs rich in NaCl are distributed does not represent route of streams along which volcanic hot waters are diluted by ground waters, for any trend of changes in that direction is observed in temperature, concentration of anions and oxygen isotope ratios. The result by Itadera et al. (2010) that has showed that the uprising of temperature in thermal waters in 1967 in the Gora area occurred first in Sokokura, eastern end of the zone, also strongly supports the above supposition. In the new model, thermal waters in Sokokura is thought to be being formed by the mixing of ground waters and hot springs rich in NaCl that does not flow into the area from the west around Soun hell, but rise up in that site from the depth.

Hot springs that are rich in NaCl are observed only in the Gora area located on the eastern side of central cones. Thermal waters flowing out in base rocks are seen only along Hayakawa and Sukumo rivers that flow toward east. Further, most hot springs are distributed in the eastern half side of the caldera and a tendency of non-overlapping is seen between the spatial distribution of hot springs and hypocenter distribution of swarm earthquakes (Yoshida, 2010). We think all of these characteristics are closely related to the existence of Tanna and Hirayama fault systems that run through in the central part of Hakone caldera in the north-south direction.

Keywords: Hakone volcano, thermal water, groundwater