Carbon isotope ratios of hot spring water in Hakone-Yumoto area around Hakone volcano, central Japan

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Oki and Hirano (1970) divided the hot spring waters around Hakone volcano, situated 80 km southwest of Tokyo in Japan, into two groups based on their chemical composition and geological structure: those that formed by volcanic activity in the central cone and those that mixed this spring water with water in the basement rocks (Haya-kawa tuff breccia, Yugashima Group). The hot spring water in Hakone-Yumoto area falls into the latter group. Kikugawa and Itadera (2008) classified the hot spring water in this area into four groups based on the chemical composition and the stable isotope ratios (δ D and δ^{18}O) and explained their genetic variety by the mixing of their end members and the dilution by surface groundwater. However, the origins of their end members and their mixing and the dilution ratios remain unclear. In the present study, we report temporal and spatial variation of the carbon isotope (δ^{13}C) values of dissolved inorganic carbon (DIC) to investigate the source of carbon in the hot spring water in Hakone-Yumoto area.

The 60 hot spring samples were collected from 2009 to 2012. The $\delta^{13}C_{DIC}$ in Hot spring water was measured using a continuous-flow isotope ratio mass spectrometer (Delta V Advantage), equipped with an automated carbonate reaction device (GasBench II, Thermo Fisher Scientific).

The obtained $\delta^{13}C_{DIC}$ values ranged from -18‰ to -1‰. We could not observe any temporal variation in the $\delta^{13}C_{DIC}$ values between 2009 and 2012. The $\delta^{13}C_{DIC}$ values increase with increasing the drilling depth and the water temperature. In some volcanic regions, some previous studies interpreted the carbon source in hot spring water as a mixture of volcanic gas-derived CO_2 and soil CO_2 (Ohsawa et al. 2002). Sakamoto et al. (1992) suggested that the magma-derived volcanic gases affected the hot spring water in Hakone-Yumoto area based on the helium isotope ratio. Our $\delta^{13}C_{DIC}$ values range between natural fumarole $\delta^{13}C_{DIC}$ in the central cone (average -1.2‰: Ohba et al., 2007) and surface groundwater $\delta^{13}C_{DIC}$ around our study area (about -18‰: Suzuki et al., 2011). Our results suggest that the hot spring waters from shallower pumping depths tend to be affected by soil CO_2, and deeper depths tend to be influenced by volcanic gas CO_2.

Keywords: carbon isotope ratio, Hakone-Yumoto , hot-spring water

