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Remote temperature sensing on volcanic fumaroles from hydrogen isotopic compositions of molecular hydrogen in the plume

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Molecular hydrogen (H_2) in a high-temperature volcanic fumarole ($>$ 400 degreeC) reach to the hydrogen isotope exchange equilibrium with coexisting fumarolic H_2O under the outlet temperature of the fumarole. In this study, we applied this hydrogen isotope exchange equilibrium of fumarolic H_2 as a tracer for the remote temperature sensing on volcanic fumaroles, by deducing the hydrogen isotopic composition of fumarolic H_2 remotely from those in volcanic plume. To verify this new remote temperature sensing actually works or not, we determined both concentrations and hydrogen isotopic compositions of H_2 in volcanic plumes emitted from the fumarolic areas showing the outlet temperatures of 630 degreeC (Tarumae), 203 degreeC (Kuju), and 107 degreeC (E-san), and compared the results with those in the fumaroles. The average and the maximum mixing ratio of fumarolic H_2 within the plume H_2 were 97 % and 99 % in Tarumae, 89 % and 96 % in Kuju, 97 % and 99 % in E-san, respectively. In accordance with the enrichment of H_2 in each volcanic plume, we found depletion in the hydrogen isotopic compositions of H_2, showing linear correlation with the reciprocal of H_2 concentration. Besides, the estimated endmember hydrogen isotopic composition for each H_2-enriched component (-260+-30 per mil vs. VSMOW in Tarumae, -509+-23 per mil in Kuju, and -437+-14 per mil in E-san) coincided well with those observed in each fumarole (-247.0+-0.6 per mil in Tarumae, -527.7+-10.1 per mil in Kuju, and -432.1+-2.5 per mil in E-san). Furthermore, the calculated isotopic temperatures in fumaroles almost corresponded with the observed outlet temperature in Tarumae and Kuju, within 20 degreeC difference. We conclude that hydrogen isotopic composition of fumarolic H_2 was quenched within volcanic plume, so that both concentrations and hydrogen isotopic compositions of H_2 in an volcanic plume enable us to deduce those in the fumarole remotely and thus the outlet temperature of fumaroles, at least for those having the outlet temperatures more than 400 degreeC. The remote temperature sensing using hydrogen isotopes (HIReTS) developed in this study can be applicable to obtain more accurate and precise fumarolic temperature in many volcanoes.

Keywords: fumarolic gases, volcanic plume, molecular hydrogen, stable isotopes, isotope exchange equilibrium, remote temperature sensing