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## Hot spring waters in basement rocks of Hakone and Yugawara volcanoes

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Hot springs that contain volcanic hot waters or are affected by volcanic gases flow out from ejecta of Hakone volcano in those areas as Owakidani, Ubako, Gora and Ashinoyu located around central cones (e.g., Kikugawa, 2009). Besides these, hot springs originally contained in cracks in Yugashima formations and Hayakawa tuff breccia that compose basement rocks flow out in Hakone-Yumoto, Ohiradai, Miyagino and Dogashima spas distributed along Hayakawa and Sukumogawa rivers. Thermal waters from cracks in basement rocks also flow out in the Yugawara area along Fujikigawa and Chitosegawa rivers, though hot springs of fossil waters that are characterized by very high concentration of NaCl are seen along seashore. In this report features of hot springs in basement rocks of Hakone-Yumoto and Yugawara areas are compared by examining concentrations of main anions, their relative concentrations and oxygen isotope ratios. Then, flow systems of those hot springs are investigated.

One of the features that are common to both of hot springs in base rocks in Hakone-Yumoto and Yugawara is that concentration of  $\text{HCO}_3^-$  is very low (for almost all of them the concentration is below 100mg/L). Others are the inverse relationship between concentrations of  $\text{HCO}_3^-$  and  $\text{SO}_4^{2-}$ , and the positive relationship between concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$ . However, it should be noted that the relationship between concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  is not one, but three types of different correlation coefficients are seen for hot springs in Hakone-Yumoto (Kikugawa and Itadera, 2008). Further, there exists such a group in Yugawara that relationship is not observed apparently between concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  due to very low concentration of  $\text{Cl}^-$ . Weak correlation is observed between concentrations of  $\text{HCO}_3^-$  and  $\text{Cl}^-$  for hot springs in Hakone-Yumoto. On the other hand, in Yugawara, in addition to the similar group, there is another type of hot spring in which such a relationship is not recognized because of very low concentration of  $\text{Cl}^-$ . The latter type corresponds to the group where relationship is not observed between concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$ .

Although, among number of types of different origin in the Gora area, such hot springs exist that concentrations of  $\text{SO}_4^{2-}$  and  $\text{Cl}^-$  are related (Kikugawa et al., 2010; Itadera et al., 2010), there is no such hot springs that possess every feature recognized in hot springs flowing out from cracks in basement rocks. The relationship between the oxygen isotope ratio and the concentration of  $\text{Cl}^-$  seems to be similar to that seen in some types of hot springs in the Gora area. However, relationships between the oxygen isotope ratio and the concentrations of  $\text{SO}_4^{2-}$  or  $\text{HCO}_3^-$  differ apparently.

Although hot springs flowing out in Hakone-Yumoto and those in Yugawara show common features as described above, clear differences can be also seen between them. For example, concentration of  $\text{SO}_4^{2-}$  for most hot springs in Yugawara is notably high compared to that for hot springs in Hakone-Yumoto. Further, as noted by Kikugawa and Itadera (2008), there are several types in hot springs in the area of Hakone-Yumoto for which concentration ratios between main anions are different. In Yugawara as well, it seems that there are multiple types of hot springs as shown above. This is considered to indicate that not one but multiple flow systems exist in each of the areas.

Keywords: hot spring, base rock, Hakone, Yugawara, dissolved constituent