VARIABITY OF DEEP SEATED FLUID OBSERVED BY RARE EARTH ELEMENTS ALONG MEDIAN TECTONIC LINE

Nakamura, H.[1,2,3,4], Iwamori, H.[5,2,3], Chang, Q.[2], Morikawa, N.[1], Kazahaya, K.[1], Takahashi, M.[1], Tanimizu, M.[6]

[1]Geological Survey of Japan AIST, Tsukuba, Japan; [2]Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan; [3]Tokyo Institute of Technology, Tokyo, Japan; [4]Chiba Institute of Technology, Chiba, Japan; [5]Earthquake Research Institute, Univ. of Tokyo, Tokyo, Japan; [6]Kwansei Gakuin University, Hyogo, Japan

Deep seated brine has been identified as a spring water upwelling in non-volcanic region in Japan. They have distinct chemical signatures such as a high-chlorine content, O-H isotopic ratios departing from the meteoric water line with no tritium, and a high $^3He/^4He$ ratio indicating a deep-origin (Matsubaya et al., 1973; Tanaka et al., 1984; Masuda et al., 1985). In addition to these geochemical characters, recent studies suggest a linkage with the slab-derived fluid, based on unconventional isotopes and elements for studies on spring waters, such as Nd and Pb isotopes and Rare earth elements (REEs) (e.g., Kazahaya et al., 2014; Kusuda et al., 2014; Nakamura et al., 2014; 2015).

The geochemical behaviour and partitioning of REEs between solid and fluid are sensitive to temperature, volatile fugacity, and pH during the upwelling processes where these parameters are potentially variable (Ohta and Kawabe, 2000). By using this sensitivity of REEs in spring waters, we have investigated the origin and upwelling processes of the deep-seated fluids along the Median Tectonic Line (MTL) in central to southwest Japan (Nakamura et al., 2016; this study).

As a result, various types of spring water have been identified. A deep brine is thought to be upwelling along the MTL and subsidiary faults, which are variably mixed with meteoric waters to precipitates REE-bearing minerals in a meteoric aquifer and evolved into spring waters with a distinct REE pattern. Rather pure meteoric waters recycling through the aquifer are widely observed in the same limited area, some of which are highly carbonated by gas with high 3He/4He derived from the deep brine. Such carbonation enhances an interaction with the host rocks of the aquifer, which may dissolve REEs (particularly light REEs) derived from host rocks.

These fluid behaviors are also distinguished by a multivariate statistical analysis (e.g., Iwamori et al., 2017). The REEs variability observed in these spring waters can be explained by three principal components (PCs) that covers ~90% of the total sample variance. (1) The first principal component PC-01 corresponds to a dilution process of deep brine by meteoric water without fractionating REEs; (2) PC-02 represents a precipitation process of REEs from the brine upon decarbonation in a deep aquifer, except for Eu which is derived from plagioclase; and (3) PC-03 represents an incorporation of REEs from host rocks by carbonation, although compositions of the host rocks may also have a significant impact on the spring water compositions. A comparison of the spring waters along the MTL has revealed a systematic geographic distribution (Morikawa et al., 2016; Nakamura et al., 2016). For instance, the deep-brines occur in the western part of the Kii Peninsula along the MTL, and the meteoric waters carbonated by the deep gas occur in the eastern part of the Kii Peninsula. The latter seems to upwell in the restricted region where deep low-frequency tremors are observed (Nakamura et al., 2016). Fluid chemistry would be a good indicator for deciphering the tectonic setting and/or temporal evolution of fluid upwelling.

References

Matsubaya O, Sakai H, Kusachi I, Satake H (1973) Hydrogen and oxygen isotopic ratios and major element chemistry of Japanese thermal water systems. *Geochem. J.*, 7:123-151.

Tanaka K, Koizumi M, Seki R, Ikeda N (1984) Geochemical study of Arima hot-spring waters, Hyogo, Japan, by means of tritium and deuterium. *Geochem. J.* 18:173–180

Masuda H, Sakai H, Chiba H, Tsurumaki M (1985) Geochemical characteristics of Na–Ca–Cl–HCO3 type waters in Arima and its vicinity in the western Kinki district, Japan. *Geochem. J*. 19:149–162

Kusuda C, Iwamori H, Nakamura H, Kazahaya K, Morikawa N (2014) Arima hot spring waters as a deep-seated brine from subducting slab. *Earth Planets Space* 66(1):119. doi:10.1186/1880-5981-66-119

Kazahaya K, Takahashi M, Yasuhara M, Nishio Y, Inamura A, et al. (2014). Spatial distribution and features of slab-related deep-seated fluid in SW Japan. *Journal of Japanese Association of Hydrological Science*, 44(1):3-16 (in Japanese).

Nakamura H, Fujita Y, Nakai S, Yokoyama T, Iwamori H (2014) Rare earth elements and Sr–Nd–Pb isotopic analyses of the Arima hot spring waters, Southwest Japan: implications for origin of the Arima-type brine. *J. Geol. Geosci. Geosci.*, 3:161, doi: 10.4172/2329-6755.1000161

Nakamura H, Chiba K, Chang Q, Nakai S, Kazahaya K, Iwamori H (2015) Rare earth elements of the Arima spring waters, Southwest Japan: Implications for fluid–crust interaction during ascent of deep brine. *J. Geol. Geophys.*, 4:5, doi:10.4172/jgg.1000217

Ohta A, Kawabe I (2000) Rare earth element partitioning between Fe oxyhydroxide precipitates and aqueous NaCl solutions doped with NaHCO: Determinations of rare earth element complexation constants with carbonate ions. *Geochem. J.*, 34:439-454.

Nakamura H, K Chiba, Q Chang, N Morikawa, K Kazahaya, H Iwamori (2016) Origin of the Arima-type and associated spring waters in the Kinki district, southwest Japan. *J. Geol. Geophys.*, 5:240, doi:10.4172/2381-8719.1000240.

Morikawa N, Kazahaya K, Takahashi M, Inamura A, Yasuhara M, et al. (2016) Widespread distribution of ascending fluids with mantle helium in the forearc region and their upwelling processes: Noble gas and major element composition of deep groundwater in the Kii Peninsula, southwest Japan, *Geochim. Cosmochim. Acta* 182:173-196, doi:10.1016/j.gca.2016.03.017

Iwamori H., Yoshida K., Nakamura H., Kuwatani T., Hamada M., Haraguchi S., Ueki K. (2017) Classification of geochemical data based on multivariate statistical analyses: Complementary roles of clustering, principal component, and independent component analyses, *Geochemistry, Geophysics, Geosystems*, 18, doi:10.1002/2016GC006663.