Origin of Arima-type brine and associated spring waters in the Kinki district, southwest Japan

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Rare earth elements (REEs) of the spring waters in the studied area, including Arima-type brine that represents a specific type of deep-seated brine of up to 6 wt.% NaCl in the non-volcanic fore-arc region, have been investigated to reveal their upwelling processes and origins [1,2]. By applying a principal component analysis of the REE data, we have identified three principal components (PCs) that cover 89% of the entire sample variance: (1) PC-01, corresponding to a dilution process by which fluids are introduced at low concentrations, previously represented by major solute binary trends, including $\delta^{18}O$–δD systematics; (2) PC-02, a precipitation process of REEs from the brine; and (3) PC-03, an incorporation of REEs from country rock by carbonic acidity, although the types of country rocks may also have a significant impact on the spring water compositions. Based on these three PCs, together with the major solute elements and $\delta^{18}O$, δD, He isotopic compositions determined in previous studies, five distinct types of spring waters were identified: (i) “Kinsen”, (ii) “Ordinary Arima”, (iii) “Ginsen”, (iv) “Eastern Kii”, and (v) “Tansansen”. These five types represent (i) a deep brine, (ii) an evolved deep brine that precipitated REE-bearing minerals, (iii) a mixture of (iii) and meteoric water, (v) a meteoric water carbonated by deep gas derived from (ii), and (i) a spring water similar to (v) with a more significant influence of the country rock constituting the aquifer. A deep brine is thought to be slab-derived fluid dehydrated from the subducted Philippine Sea slab beneath the Arima area [1,3]. Comparing the spring waters in the Arima and Kii areas, a systematic geographic distribution has been revealed: the “Ordinary Arima”-type occurs along the Median Tectonic Line, while the “Eastern Kii”-type occurs in the eastern part of the Kii area where the deep low-frequency tremors are observed. The geographical distribution seems to be linked to the tectonic setting and/or temporal evolution of fluid upwelling [4].

[1]Nakamura et al. (2014) *J.Geol.Geophys.*[2]Nakamura et al. (2015) *J.Geol.Geophys.*[3]Kusuda et al. (2014) *Earth Planets Space* [4]Nakamura et al. (in review) *J.Geol.Geophys.*