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 δ18O–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 δ18O, 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].