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Rare earth element composition of the Arima-type brine and its implication for slab-derived fluid

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The Arima-type brine has been known as one of the oldest hot springs in Japan, as well as its distinct geochemistry: in spite of its presence in the non-volcanic region in the forearc, the oxygen and hydrogen isotope compositions show a presence of deep brine similar to volcanic fluids. Mixing between the meteoric water and a deep brine with a high 18delta-O and delta-D (7 to 8, -40 to -30, respectively) explains the linear trend of the brine samples. The Arima-type brines are highly concentrated in the type locality, Arima, SW Japan. The two plates subduct beneath the area: the Pacific Plate subducts from the east and underlies ~400 km below the area, whereas the Philippine Sea Plate subducts from the southeast and is seismically observed 50 to 80 km below the area. In spite of this active subduction, there is no Quartenary volcano in this area, possibly because the Pacific Plate is too deep and the Philippine Sea Plate is too shallow to fulfill the physicochemical conditions for arc magma generation.

Here we report geochemical signatures, in particular the REE concentrations, of the Arima brine, and suggest that it could have originated directly from the subducting slab without any significant modification during its ascent. High salinity, high 3He/4He ratio and distinct oxygen, hydrogen and carbon and strontium isotope compositions also suggest that they have been derived possibly from the subducting Philippine Sea slab, hence may bring invaluable insights for the slab-derived fluid and the related fluid processes in subduction zones. In this study, we analyzed samples from ‘Kinsen’. The Kinsen brine has a high salinity and the highest abundances of the trace elements in this area. We have also sampled a solid material precipitated within the pipe, in order to estimate the elemental fractionation during cooling of the hot spring and precipitation from it. Because of its high salinity (up to 6 wt.% NaCl) of the Arima-type brine, the matrix effects are extremely large to prevent accurate analysis of any trace element. We employ a standard addition method, aiming at rapid yet accurate analyses.

The DMM normalized composition of Arima brine exhibits broadly a flat pattern around the normalized concentration of 10-3 with a convex-down shape for mid-REE, except for positive anomaly in Eu. On the other hand, the precipitates consist of aragonite and magnesite, which do not contain REE above the detection limit, except for Gd which is likely derived as flakes from the pipe.

Alternatively, based on the reported partition coefficient and the numerical modeling of the thermal structure along the subducting slab, the REE concentrations in the slab-derived fluid (as a product of slab dehydration reactions) have been evaluated. The calculation results broadly coincide with the observed REE concentrations of the Arima-type brine. Together with these analytical results and forward calculation, we conclude that the REE composition in the Arima brine is straightly originated from the dehydration of subducting slab at 450 degree.

Keywords: slab-derived fluid, Arima brine, rare earth elenents, isotopic compositions of oxygen and hydrogen, Arima-type brine, subduction zone