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LF-earthquakes, S-wave reflectors and Arima-type Brine: A model for Geofluid circulation in arc crust

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<Introduction>: Kazahaya et al [2011] reported distribution of ”Arima-type brine” in various part of Japan and they proposed that it represents fluid from deep source. ”Arima-type brine” is featured by 1) high salinity: >3 times of sea water, 2) high CO2, 3) oxygen and hydrogen isotopes similar to those of island-arc andesite magmas. They proposed that it may have two origins 1) fluids derived from dehydration of subducting oceanic plate, 2) fluids derived from solidifying magma in the lower crust. Because of its vital importance in understanding the nature of deep fluids, I discuss the origin of ”Arima-type brine” in the latter case.

<”Arima-type brine” originated from crustal partial melt>: Considering average heat flow and distribution of Quaternary volcanoes in Japanese island arcs, temperature of the lowermost crust would be >800degC and small amount of partial melt would exist almost ubiquitously regardless of the distribution of the Quaternary volcanoes. If partial melting takes place in the lower crust, aqueous fluids derived from subducting plates and those migrating in the mantle wedge should be trapped there and the composition of fluids in the crustal depth should be controlled by melt/fluid equilibrium at the base of the crust. Very high Cl and CO2 featuring ”Arima-type brine” can be easily understood by considering melt/fluid element partitioning at the lower crustal depth, because Cl strongly partitions into fluid [2] and its CO2 solubility is high.

<Water eruption during the Matsushiro Earthquake Swarm>: More than 60000 earthquakes took place in Matsushiro, central Japan in 1965-1967 [Mogi, 1989]. Matsushiro earthquake swarm is featured by ejection of large amount of saline ground water since 1968 until today. Tsukahara and Yohida[2005] discussed the origin of the ground water eruption associated with Matsushiro earthquake swarm and proposed a model that the water may have derived from mid crustal ”S-wave reflector” which is a reservoir for deep crustal fluids. Chemistry of the ground water (including isotopes) ejected from Matsushiro is indistinguishable from that of the ”Arima-type brine”. The ”groundwater eruption” in Matsushiro strongly suggests that ”Arima-type brine” may be stored at some crustal level locally in large volume. ”S-wave reflectors” found in many areas in Northeast Japan (typically at 10˜15km depth, [Hasegawa et al.2005]) may correspond with the deep crustal ground water reservoirs. Very low electric conductivity anomalies found in middle crust of subduction zones [Ogawa,Y. et al, 2007] may also represent reservoirs for high salinity crustal fluids.

<Formation of ”S-wave reflectors”>: Close correlation has been found between location of the lower crustal DLF earthquakes and the distribution of the middle crustal ”S-wave reflectors” in Northeast Japan. If lower crustal DLF earthquakes correspond with the emission of fluids from solidifying magma body, fluids derived from lower crustal magma should have >5wt% SiO2 as well as Cl and CO2. Thus, large amount of silica and carbonate must precipitate from the fluid along ascent due to decreasing temperature and pressure. Deep fluids may be self-sealing as it ascends due to the precipitation of silica and carbonate. Judging from the depth distribution of the ”S-wave reflectors” (reflectors situate at shallower depths near volcanoes), the depth of precipitation may be more sensitive to ambient temperature than pressure.

<Summary>: In summary, I propose that known features of the ”Arima-type brine” may be explained in a coherent manner by considering melt/fluid equilibrium at deep crustal condition. Shallow crustal process (such as precipitation of silica and carbonate) would determine its final chemistry.

Keywords: Arima type brine, low frequency earthquake, S-wave reflector, Matsushiro earthquake swarm, geofluid circulation