Fate of slab water in arc–backarc–stagnant slab and beyond

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We present results of petrological examinations on residual water in the subducted Pacific Plate oceanic plate slab beneath NE Japan subduction zone, the Sea of Japan backarc basin, and East Eurasia stagnant slab in the mantle transition zone (MTZ). Water mass balance in this cold subduction system is particularly important in understanding deep water cycle. Subducted slab is believed to be saturated by water in its sediment and igneous oceanic crust layers, whereas penetration of water into the slab peridotite is limited to be as much as 1 wt% water on average based on the seismic observations before and beneath the subduction zone. Given this initial condition, slab dehydration is calculated using Purple_X thermodynamic model in combination with geodynamic slab geotherm calculated for NE Japan subduction zone under mantle potential temperature Tp = 1350 ˚C. The results indicate that almost all slab water is released by the depth of 410km before MTZ leaving only ˜300 ppm water in the entire slab. This is consistent with the deep upper mantle seismic tomography images showing low velocity mantle beneath the NE Japan arc and the Sea of Japan backarc basin suggesting continuous water release from the slab in 60–410 km depth range. Water contents in the mantle sources of basalts erupted on the NE Japan magmatic arc, in the Sea of Japan backarc basin, and in the East Eurasia intra plate basalts above stagnant slab are estimated to be 10,000 –50,000 ppm, >500 ppm, and 300–600 ppm, respectively. The hydrous arc basalts are rich in fluid-mobile elements reflecting an intensive dehydration of the slab in the depth range 60–180 km. Enriched (E)-type backarc basin basalts have isotopic slab sediment signatures and depleted (D)-type basalts have very depleted MORB-like source due to addition of water to >500 ppm from the slab in tandem with the high Tp = 1450˚C. The East Eurasia basalts of intra-plate type generally lack isotopic signatures from the subducted Pacific Plate except for the basalts around Shandong which involve carbonated igneous oceanic crust from the Pacific Plate slab with low water content. Common source for the East Eurasia basalts is supposed to be undepleted deep mantle with water content 300–600 ppm melted adiabatically under Tp = 1450˚C. Such the deep mantle is supposed to have upwelled by breakoff of the stagnant slab and subsequent slab rollback which triggered opening of the Sjapan Sea backarc basin in the Oligo-Miocene. The geo-traverse of the basalt chemistry across the subduction zone–backarc basin–stagnant slab suggests wettest subarc, wet backarc, and dry deep barckarc mantles on the stagnant slab supporting the results from petrological slab dehydration model above. Above examinations imply that the subducted plate slab has desiccated by the depth of MTZ even in the coldest subduction zone so that amount of ocean water returned to the lower mantle is fairly limited.

Keywords: Slab dehydration, Subduction zone, Mantle transition zone

