EGU22-2121
https://doi.org/10.5194/egusphere-egu22-2121
EGU General Assembly 2022

Spontaneous formation and evolution of a weak hydrous layer at a slab interface: a numerical perspective

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The cold forearc mantle is a universal feature in global subduction zones and attributed to mechanically decoupling by the weak hydrous layer at the sub-forearc slab interface. Understanding the mechanical decoupling by the weak hydrous layer thus provides critical insight into the transition from subduction infancy to mature subduction since subduction initiation. Nevertheless, the formation and evolution of the weak hydrous layer by slab-derived fluids and its role during the transition have not been quantitatively evaluated by previous numerical models as it has been technically challenging to implement the mechanical decoupling at the slab interface without imposing ad hoc weakening mechanism. We here for the first time numerically demonstrate the formation and evolution down-dip growth of the weak hydrous layer without any ad hoc condition using the case of Southwest Japan subduction zone, the only natural laboratory on Earth where both the geological and geophysical features pertained to the transition since subduction initiation at ~17 Ma have been reported. Our model calculations show that mechanical decoupling by the spontaneous down-dip growth of the weak hydrous layer converts hot forearc mantle to cold mantle, explaining the pulsating forearc high-magnesium andesite (HMA) volcanism, scattered monogenetic forearc and arc volcanism, and Quaternary adakite volcanism. Furthermore, the weak hydrous layer providing a pathway for free-water transport toward the tip of the mantle wedge elucidates seismological observations such as large S-wave delay time and nonvolcanic seismic tremors as well as slab/mantle-originating geochemistry in the Southwest Japan forearc mantle.