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A preliminary model of water circulation in the mantle with tectonic plates, basaltic piles, and magmatism

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Numerical models of mantle convection are developed to understand how tectonic plates and the piles of subducted oceanic crusts, often called superplumes, influence the water circulation in Earth's mantle. Tectonic plates and ridge and plume magmatism are self-consistently reproduced in the model, but island arc volcanism is neglected for simplicity. When the internal heating rate by radioactive elements is comparable to the value expected for the present Earth's mantle, broad piles of subducted basaltic crusts develop on the core mantle boundary and plates move in a well-ordered way. The water that diffused into the tectonic plates are efficiently transported into deep mantle with a characteristic time of billions of years. A part of the water accumulate in the basaltic piles, but the rest returns back to the surface to enhance ridge and plume magmatism. In contrast, the basaltic piles become convectively unstable when the internal heating is as strong as expected for the early mantle. The thermal buoyancy induced by the strong internal heating frequently causes bursts of the mantle materials that contains subducted basaltic crusts from deep mantle to the surface and induces vigorous magmatism. Plate motion becomes chaotic because of the lithospheric rupture caused by the frequent vigorous magmatism. The vigorous and frequent magmatism as well as the chaotic plate motion inhibit deep penetration of water into the mantle and keeps the mantle rather dry. Though the water extraction from subducting slabs by island arc volcanism is not yet taken into account here, the models do suggest that the Earth's mantle has evolved from a dry state in the early Earth to a wet state in the present Earth.

Keywords: water circulation, plate tectonics, basaltic pile, mantle evolution, numerical model