Geophysical Research Abstracts
Vol. 17, EGU2015-10463, 2015
EGU General Assembly 2015

Slab dehydration and deep water recycling through time

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The fate of water in subduction zones is a key feature that influences the magmatism of the arcs, the rheology of the mantle, and the recycling of volatiles. We investigate the dehydration processes in subduction zones and their implications for the water cycle throughout Earth's history. We use a numerical tool that combines thermo-mechanical models with a thermodynamic database to examine slab dehydration for present-day and early Earth settings and its consequences for the deep water recycling. We investigate the reactions responsible for releasing water from the crust and the hydrated lithospheric mantle and how they change with subduction velocity, slab age, and mantle potential temperature.
Our results show that faster slabs dehydrate over a wide area: they start dehydrating shallower and they carry water deeper into the mantle. A hotter mantle (i.e. early Earth setting) drives the onset of crustal dehydration slightly shallower, but, mostly, dehydration reactions are very similar to those occurring in present-day setting. However, for very fast slabs and very hot mantle epidote is involved as a dehydrating crustal phase. Moreover, we provide a scaling law to estimate the amount of water that can be carried deep into the mantle. We generally observe that a 1) 100°C increase in the mantle temperature, or 2) $\sim$15 Myr decrease of plate age, or 3) decrease in subduction velocity of $\sim$2 cm/yr all have the same effect on the amount of water retained in the slab at depth, corresponding to a decrease of $\sim$2.2x10^5 kg/m2 of H_2O. We estimate that for present-day conditions $\sim$26% of the global influx water, or 7x10^8 Tg/Myr of H_2O, is recycled into the mantle. Using a realistic distribution of subduction parameters, we illustrate that deep water recycling might still be possible in early Earth conditions, although its efficiency would generally decrease. Indeed, 0.5-3.7x10^8 Tg/Myr of H_2O could still be recycled in the mantle at 2.8 Ga.