Geophysical Research Abstracts
Vol. 20, EGU2018-13345, 2018
EGU General Assembly 2018

Modelling dehydration and water migration in subduction zones – a two-phase flow approach

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The progressive release of water by metamorphic dehydration induces important physical-chemical processes, which have been invoked to explain many geophysical and petrological observations in subduction zones. These observations include: subduction-related volcanism, earthquakes, hydration of the mantle wedge, and rehydration of the oceanic slab during the bending of the subducted plate. Yet, how dehydration and associated water migration in the system progresses over time and with increasing depth has not been fully explored by numerical models until now. Here, we investigate this problem by incorporating Perplex-based dehydration reactions into a thermo-mechanical modelling framework in which the released fluids are treated as porous fluids and migrate through the solid medium using a two-phase flow formulation. This framework allows us to investigate the fluid migration not only in the mantle wedge, but also in the oceanic slab, with self consistent consideration of different subduction regimes. Three different types of rock are used in our models for the dehydration processes, with bulk compositions taken from Hacker (2008): mid-ocean ridge basalt (MORB), gabbro, and depleted MORB mantle (serpentinized mantle). Based on the pressure and temperature field from the subduction model, the mineral-bound water in these rocks is updated through time and water releases as free water in the poro-space (i.e. porosity). We run a set of models with different fluid migration properties of the mantle and look into different subduction regimes (i.e. stable subduction, trench retreat and advance). Our results show that the dehydration-generated porous water can migrate following three principal paths: (1) Updip along the slab and into the cold corner of the mantle wedge; (2) Up into the asthenospheric portion of the mantle wedge ; and (3) Down into the deep oceanic slab. These model results are consistent with geophysical and petrological observations of subduction zones worldwide and will help improve our understanding of fluid-related process in these systems.