



The dynamics of reactive fluid escape in subduction zones

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At subduction zones seawater-altered oceanic lithosphere is returned to the Earth's mantle, where increasing pressures and temperatures cause the progressive destabilization of hydrous minerals to liberate immense quantities of aqueous fluids. Understanding the mechanism and non-lithostatic fluid (thermo)dynamics of how fluids are liberated and escape from the subducting oceanic plate is key to develop a quantitative understanding of geochemical cycles and geodynamical processes associated with subduction zones. Fluids released from the subducting slab induce sub-arc mantle melting causing volcanism and induce petrophysical changes during dehydration that can lead to intermediate-depth seismicity. In all these cases large-scale transport systems need to form, where fluids are able to escape from the subducting slab to either migrate up-dip along the subduction channel or into the overlying mantle wedge. Nevertheless, permeability is minimal at the depths and confining pressures relevant to subduction settings, thus insufficient to allow for pervasive fluid flow with high enough fluxes to efficiently drain the subducting oceanic plate. Evidence from the volatile cycle indicates that a fluid extraction mechanism must exist that can keep pace with the slab descent velocity of cm/year to avoid the fluid being lost to the mantle. The tendency of fluid flow to occur channelized in space and time, demonstrated in almost all high-pressure terrains as vein networks, points to a possible mechanism. Channelized fluid flow would enable efficient fluid release rates with high local fluid fluxes over long distances. However, the unresolved questions is; how does a dehydrating system with an intially low, pervasive fluid production develop into a channelized fluid extraction network, allowing effective large-scale fluid transport? By using a combined approach of field observations, reaction microstructures down to the nanoscale and state-of-the-art numerical modelling we investigate one of the most prominent dehydration reaction for the deep volatile cycle, the breakdown of antigorite to form anhydrous olivine. For the first time we are able to link micro- to nanoscale breakdown reaction microstructures characteristic of initial fluid pooling to the development of large-scale, channelizing dehydration vein networks. On the basis of our findings we formulate a consistent mechanistic model of metamorphic fluid escape during mineral dehydration.