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Retrogressive Metamorphism: Mechanisms of Fluid Introduction to Impermeable Rocks

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The metamorphic cycle is likely to produce a lower crust containing little or no free fluids. Introduction of external fluids to such dry and impermeable volumes of the Earth's crust is thus a prerequisite for retrogressive metamorphism and may furthermore cause significant changes of the crust's physical properties, notably its density, rheology, and geophysical signature. Yet, the mechanisms controlling how fluids get into dry rocks remain controversial. On a large scale, fluid introduction requires the presence of high permeability channel-ways, such as faults or fractures. Such channel-ways are the results of external tectonic stresses. However, the actual interaction between the externally derived fluids and the fractured rocks in the crust requires efficient and pervasive mass transport away from the initial fractures into the rocks. This transport often occurs over distances much longer than expected from grain boundary diffusion. Here we present combined field observations and network models that demonstrate how effective and pervasive fracture controlled transport of fluids into initially dry rocks is accelerated by several orders of magnitude due to the perturbations on the local stress fields caused by heterogeneous metamorphic reactions. We analyse both the situation of positive and negative solid-volume changes and furthermore show how the morphology of reaction fronts associated with this transport depends on anisotropies in the external stress field.