Nanoscale control on fluid-driven, crustal metamorphism

OLIVER PLÜMPER[1], ALEXANDRU BOTAN[2,3], YANG LIU[1,4], BJØRN JAMTVEIT[2]

[1]Department of Earth Sciences, Utrecht University, Budapestlaan 4, Utrecht, The Netherlands (o.plumper@uu.nl)

[2]Physics of Geological Processes (PGP), University of Oslo, Blindern, N-0136 Oslo, Norway

[3]Centre for Materials Science and Nanotechnology, University of Oslo, Blindern, N-0318 Oslo, Norway

[4]Debye Institute for Nanomaterials Science, Utrecht University, Princetonplein 1, 3584 CC Utrecht, The Netherlands

Fluid flow through the Earth's crust controls element redistribution to form mineral deposits, the release and sequestration of greenhouse gases, and it facilitates crustal metamorphism by influencing lithospheric rheology. In permeable systems with a well-connected pore space, fluid transport is largely governed by fluid pressure gradients. In impermeable rocks, deformation may induce permeability by creating interconnected heterogeneities, but without these perturbations, fluid transport is limited along grain boundaries or relies on transformation processes that generate fluid pathways. The latter can facilitate large-scale fluid and mass transport in nominally impermeable rocks without large-scale fluid transport pathways. Using multi-dimensional imaging down to the nanoscale we investigate the formation mechanisms of fluid pathways during pervasive, fluid-driven metamorphism of igneous feldspathic rocks. We show that feldspar replacement reactions affecting an area of >60 km² are directly linked to the production of nanoscale porosity (<100 nm). Consistent with experiments [e.g., 1], our results show that interconnected pore space emerges and evolves dynamically as a result of dissolution-precipitation and is thus independent of tectonic forcing and deformation. Determination of fluid transport coefficients through feldspar nanopores derived from (non-equilibrium) molecular dynamics simulations coupled to continuum-scale fluid mechanics suggests that fluid and mass transport can be self-generated through the emergence of electrokinetic transport processes and may not rely on fluid pressure gradients. In conclusion, the self-induced creation of fluid pathways and associated nanoscale transport processes may considerably aid pervasive, fluid-driven metamorphism and metasomatism in the Earth's crust.

[1] Raufaste, C. et al. The mechanism of porosity formation during solvent-mediated phase transformations. *P. Roy. Soc. Lond. A Mat.* **467**, 1408-1426 (2011).