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Porosity developed during mineral replacement reactions: implications for fluid flux in the Earth

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Aqueous fluids, that are ubiquitous in the crust of the Earth, will move through possible pathways in rocks. Rocks characteristically have low permeability but fractures can provide fast fluid channels. Mineral grain boundaries also present easy fluid pathways. However, porosity within minerals forms when a mineral is out of equilibrium with an aqueous fluid and reactions take place in an attempt to reach a new equilibrium. Commonly, dissolution at a mineral-fluid interface initiates one or several coupled reactions involving dissolution and precipitation (Putnis C.V. and Ruiz-Agudo E., 2013; Ruiz-Agudo et al., 2014). In pseudomorphic volume-deficit reactions, a new phase forms while porosity is created, and thereby reactive fluid flow through the originally solid mineral is enhanced. These coupled dissolution-replacement reactions therefore will constrain the flux of material carried by the fluid. These reactions are common during such processes as metamorphism, metasomatism, and weathering. When rock-forming minerals such as feldspars, olivine, pyroxenes and carbonates are in contact with aqueous fluids (typically NaCl-rich) porosity is formed during the interfacial replacement reactions. Elements present in the parent mineral are released to the fluid and therefore mobilized for transport elsewhere.
Porosity formation has been shown in a number of systems, such as during the albitisation of feldspars (Hövelmann et al., 2009) and the replacement of carbonates by apatite phases (Pedrosa et al., 2016). Some of these examples will be presented as well as examples from atomic force microscopy (AFM) experiments used to image these reactions at a nanoscale, especially at the calcite-fluid interface, when new phases can be directly observed forming. This mechanism has also been shown as a means of carbon and phosphorus sequestration and for the removal of toxic elements from superficial waters, such as Se and As.

References

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